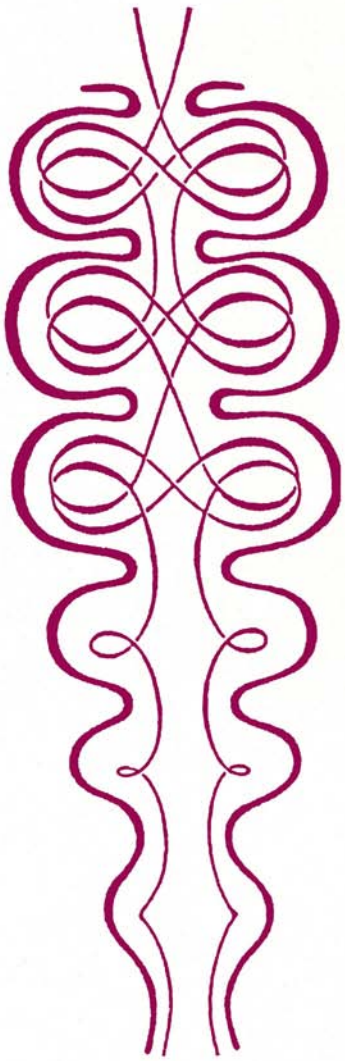
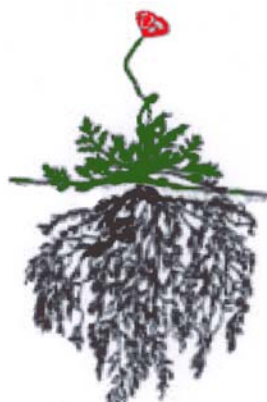


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Spring 2006



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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VOL. 12, #22

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FROM THE EDITOR

Because of increased demands from work and family, John Petering has had to step back from his association with the *Waldorf Science Newsletter*. We hope that he will rejoin us in the future, thank him for his past contributions, and wish him well.

I am overjoyed that Bob Amis has agreed to become a partner. Please read more about Bob on page 5 of this edition.

This issue of the *Newsletter* contains the first of a two-part article on lenticular clouds from Julius Tonelli, a teacher at the Washington Waldorf High School, an article on mathematics and natural science from Georg Kniebe, an introduction to using new technology for Surveying in the 10th grade by Peter Glasby and colleagues from Australia, a guide to building a scale model of Kepler's model of the universe, as well as an article on "Animal Vision," and an archived article from John Davy on "The Life of

an Insect." There is also an article on "Teaching Sensible Science" workshop sponsored by the Research Institute for Waldorf Education. The editors strongly recommend that every school has one or many teachers attend this valuable workshop. There are several related experiments from Bob Amis who attended the first of the Workshop series.

We wish to point out the noteworthy achievements in science from Waldorf schools in Germany that are described on the next page.

As always, we welcome your comments, contributions, requests, and involvement to make this *Newsletter* a vital aspect of developing phenomenological science in our Waldorf schools. We would also appreciate hearing about areas in which our readers would like more information and in-depth articles.

We wish you all a fruitful and wonderful spring term.

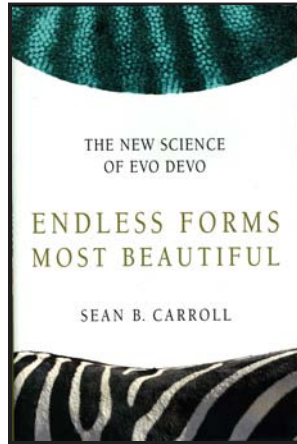
Books of Interest

Endless Forms Most Beautiful

by Sean B. Carroll

This integrative study shows how two of life's great transformations, the development passage from egg to adult and the evolutionary stages of the human being, find common explanation in the biology of genes.

"The greatest spectacle of life is how a single cell – the fertilized egg – develops into a billion- or trillion-celled animal. As it turns out, the miracle of complex life is more amazing, yet ironically simpler, than anyone ever expected." (from the introduction)



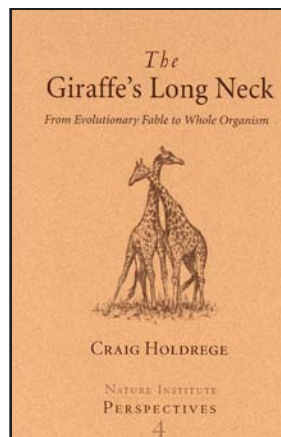
ISBN #0-393-06016-0

350 pages

The Giraffe's Long Neck From Evolutionary Fable to Whole Organism

by Craig Holdrege

This book, complete with many sensitive drawings and photographs, brings the giraffe as a whole organism to our consciousness. Craig shows the interconnectedness of the giraffe's features and how an observer can begin to both grasp it as an integrated whole and gain a sense for its overall integrity. This book will please teachers of all levels, high school students, and individuals who have a love of the animal kingdom.



ISBN #0-9744906-3-6

104 pages

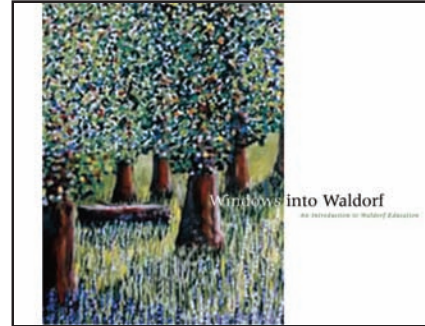
5.5 x 8.5 inches \$10.00

AWSNA Publications

Windows into Waldorf

by David Mitchell

Art Editor: Hallie Wootan



This booklet introduces new parents, grandparents, and others wishing to have a look through a window at some of the fundamentals of Waldorf education. The first half of the book give glimpses into the broad scope and foundation upon which the pedagogy stands – it is richly illustrated with colorful photographs that give the reader a “feel” of the texture of Waldorf. The second half of the book contains three short essays examining the developmental phases of thinking through the subjects of history, geometry, and the sciences. This section is alive with illustrations from student notebooks, workshops, crafts studios, and fine art studios.

There are two pages of testimonials from the current prime minister of Norway, Jens Stoltenberg, Willi Brandt from Germany, an astronaut, a famous conductor, several prominent academicians, and a Nobel prize winner, to name a few.

The back cover has a pocket where schools can individualize the viewbook by placing their own brochure and relevant admissions material.

There is a pocket in the back that schools may use to customize by inserting their own brochures or other school information.

ISBN #1-888365-61-7

40 pages

11 x 8.5 inches

Price TBD

AWSNA Publications

To be available in April 2006

Advance orders are welcome and encouraged.

Editor: Stephen Keith Sagarin, PhD

Every teacher should be both a subscriber and a contributor to the *Research Bulletin*. Dedicated to furthering research in education this international publication provides schools with studies and data that place Waldorf education at the forefront of the educational scene in North America. Key topics in this issue are: Puberty as the Gateway to Freedom; Soul Hygiene and Longevity for Teachers; The Emergence of the Idea of Evolution in the Time of Goethe; The Seer and the Scientist. If you have not seen the latest edition, you are encouraged to obtain a subscription from:

researchinstitute@earthlink.net.

72 pages

7.5 x 11 inches \$12.00 Write for bulk prices

Research Institute for Waldorf Education &
AWSNA Publications



Introducing Bob Amis

It is my pleasure to introduce Bob Amis as the new assistant editor for the *Waldorf Science Newsletter*. Bob is in his fourth year as a teacher at the City of Lakes Waldorf School in Minneapolis, Minnesota. After a career in business, Bob took up the teaching



mantle, taking a class for grades seven and eight, and then another class for grade eight. This year he is providing support in science and math to the upper grades teachers as well as implementing a wilderness skills and awareness curriculum for grades one through eight.

Solar Cells Made of Blueberry Juice and Glass Panels

German Waldorf Students Compete
Successfully in National Competitions

– Stuttgart (NNA)

In contrast to public preconceptions, Waldorf pupils are quite capable of holding their own in science and technology and other fields in competition with students from state schools. This was illustrated most recently in prizes won by pupils from Rudolf Steiner schools in Germany.

According to a list published by the Association of Waldorf Schools in Stuttgart, Veronika Apel, Jonathan Binas, Johannes Gantner and Mark-Felix Schütz from class 12 of Darmstadt Waldorf School won first prize in a competition organized by the regional body of the Association of German Engineers (VDI). They built a fully working solar cell from blueberry juice, the graphite from a lead pencil and two nanocoated glass panels. The idea arose during a biology lesson on photosynthesis.

In the field of computing, the national “Young Researchers” competition included Justus Menzel from the Hamburg Rudolf Steiner School among the prize winners, who together with his friends invented a new keyboard layout which improves typing speed by up to 25 percent. “The traditional typewriter keyboard was invented 130 years ago such as to ensure that people could not type too fast so that the keys would not stick,” the 17-year-old innovator explained. The students intend to market their prize-winning keyboard.

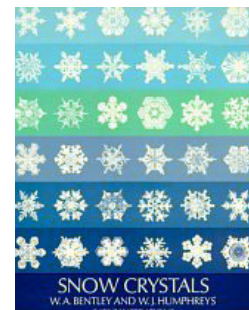
In business competitions, Waldorf pupils also do well. This was illustrated in last year’s national “Young Entrepreneurs” competition. Lennart Grumer from the Kräherwald Free Waldorf School in Stuttgart and his team won third prize in the competition, which attracted 1500 entries, for their business plan and marketing concept for a solvent-free, environmentally friendly glue which another student from Stuttgart had developed as part of the “Young Researchers” competition.

“We developed a corporate identity for our fictitious company, Creative New Productions CNPro, with a socially aware corporate philosophy which nevertheless produced a return of 15 percent on turnover,” Lennart Grumer said.

Preserving a Snowflake



The hexagonal form, in its many metamorphosed variations as represented in the snowflake, has fascinated me since I was a small boy studying them as they landed on my deep blue mittens. Later as a young teacher I came across W. A. Bentley's inspiring book *Snow Crystals* (right) which contains 2453 photographs of snowflakes, each one uniquely taken over a 27-year period in Vermont. The snowflakes are ethereally beautiful, and the variety is just stunning. Bentley was a man of genius and dedication, and this book is a classic.



During cold New England days my class and I would rush out to the playing fields of the Pine Hill Waldorf School with sheets of black construction paper to capture snowflakes floating softly down from the white sky. With delight and wonder we would look at each others' fragile crystalline miracles until a warm breath or inquisitive finger transformed them into wetness and we learned a lesson about the transitory nature of beauty.

Last week while reading the magazine *Popular Science* I came across a simple method for preserving a snowflake that I have adapted below.

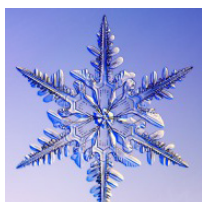
Materials:

A 4-inch by 4-inch piece of black construction paper, plastic tweezers (optional), clear viscous super glue (not gel), glass microscope slides, and quartz coverslips. [The microscope slides (#10-1305-12, \$9.50/72 slides) and cover slips (#10-1305-21, \$6.25/100 coverslips) can be obtained from your high school biology teacher or ordered online at:

> [.](https://www.sciencelab.com/page/S/PVAR/20711/10-1305-12<)

Procedure:

1. Select a snowy day when the temperatures are at 20°F or below. The slides, coverslips, and tweezers should be left outside for 15 minutes to chill. The children can now take their black construction paper and see if they can capture several snowflakes. They can also capture them directly on the microscope slide if they hold the slides on the edges with their fingertips.
2. With the cold plastic tweezers select a special snowflake and position it in the center of a slide. If tweezers are not available you can shake the snowflake onto the slide from the paper and use the corner of the paper to carefully position it.
3. With children below the fifth or sixth grade, they come to the teacher who places a drop of the superglue directly on the snowflake. Note: teacher discretion is also advised with older children as superglue is an eye irritant. In any case read the safety instructions that come with the product you purchase and practice due diligence.
4. Next the teacher carefully drops a coverslip directly on top of the superglue. Handle the coverslip only by the edges and do not press it into the glue (the snowflake may melt as a result of friction). Gravity should settle it nicely.
5. Immediately, place all the slides in a freezer for about 10 days to allow the superglue to harden completely. At this point each snowflake is preserved and will not melt.
6. You can now tape the slides to a window or place the slides on black construction paper and marvel at the multiplicity of forms, all related to the hexagon, that the class has collected.
7. If you wish to carry the observations further, you can create hexagonal pieces of paper, have the class fold them, and then cut individualized snowflakes with scissors to decorate the classroom.



DSM

Environment, Morphology, and Physical Principles for Waldorf High School Teachers and Students

by

Julius E. Tonelli

Part One of Two Parts

Introduction and Acknowledgements: Lenticular Clouds or Just Clouds?

When I began to write about lenticular clouds, I did so mainly out of an intense interest in their weirdness and aliveness. I wanted to know how they formed, and why they stayed stationary in spite of the high winds that normally exist all around them. I wondered why they surfed in place where the air was obviously passing around and perhaps through them. I had seen many of them, was very familiar with their appearance, and knew the large-scale processes with which they were associated. I hoped very much to discover whether they were a topic worthy of study in a Waldorf high school physical science class.

I therefore wrote about them, at first contextually, placing lenticular clouds in their place in the pantheon of all clouds, and then phenomenologically, considering only my observations concerning lenticular clouds and related phenomena. I described them and the surrounding weather and environment as best I could. As I wrote, I knew intuitively that I was not just talking about lenticular cloud formation, even though the words on the page were all about lenticular cloud formation! I wrote roughly 25 pages of how they form and what one needs to know about physics to understand them. But intuition told me that that was not really my subject.

When I brought the paper to the Center for Anthroposophy during the Summer Training Session for 2005, I asked to air (no pun intended) the paper during a physical science class. The instructor and the students agreed.

As such, the study of the limited case of lenticular clouds can lie at the heart of any phenomenologically-derived physical science course at any school whose location includes the intermittent existence of these strange sky dwellers. This paper answers some of the questions of how, when, and where to recognize these clouds, with which students they may best be studied, and related areas needing far more research.

PART I

Some Observations of Lenticular Clouds and Closely Related Phenomena

A: Lenticular Clouds over the Washington, DC, Area

November 3, 2004, 9:00 A.M. Washington Waldorf School, Bethesda, MD: Optics Main Lesson. We are outdoors looking at shadows cast in direct sunlight and are trying to observe the *heilighenschein* [halo]. The day before had been clear, warm, and humid for that time of year; a moderate wind blew from the southwest. This morning features a gusty wind from the northwest; it's crisp and much colder. As we observe the shadows, we are hampered by a cloud problem: A middle level (around 15,000 feet above the ground), wave-shaped cloud keeps forming and dissolving, its elongate southeast edge just barely

eclipsing the sun. It seems to move only a little, sometimes backing up towards the northwest, uncovering the sun, while at other times advancing to the southeast to block it. This interfered with our shadow observations.

On closer inspection, we see the cloud fade and reform over an elongate portion of sky. It is oriented so its long dimension is perpendicular to the surface wind, (blowing in from the northwest.) The cloud stretches northeast to southwest for miles, almost from horizon to horizon, but it is only half a mile to a mile across in the short direction. It is at most 1000 feet thick, with much thinner places. The cloud is unevenly thickening up and thinning out along its length. Stunningly unique about this cloud is its smoothness – from afar, most of its edge resembles the skin of a frog’s underbelly. True, there are a few puffs and plumes rising from it, but for the most part, the surfaces of this cloud are free of the curls, twists, and cauliflower-shaped promontories that exist so often in other wind-torn skies.

There are times when it wavers such that its edge is solidly over the sun, nearly causing the Optics class to despair of completing our shadow and *heiligschein* observations; yet as we begin to head back into the school building, the sun suddenly emerges again as the cloud shrinks backwards against the wind. We resume our observations again in the 5-minute reprieve. Then it swells again, covering up the sun.

Never does the cloud travel across the sky, as one often sees with fair-weather cumulus clouds, or pre-storm stratus, or post-storm mackerel skies. Unlike these clouds which move horizontally and vertically with time, this cloud is stationary. This is so despite very strong winds, gusting to 35 miles per hour on the surface. There appear to be strong winds aloft as well: at elevations of some 30,000 feet are 8 contrails running parallel to our subject cloud, but migrating sideways quickly to the southeast – indicating strong northwest winds high aloft. At 5000 to 10,000 feet there are a few cumulus clouds and low-flying single engine aircraft. The cumulus are moving quickly southeastward while the planes trying to fly southwestward must tack (fly pointed somewhat into the wind) northward to maintain their southwest travel over the ground, see Figure 1.



Figure 1

Our cloud seems to cut through the wind as would the airfoil of any wing. In fact, the cloud resembles an airfoil in its cross-sectional shape, see Figure 2.

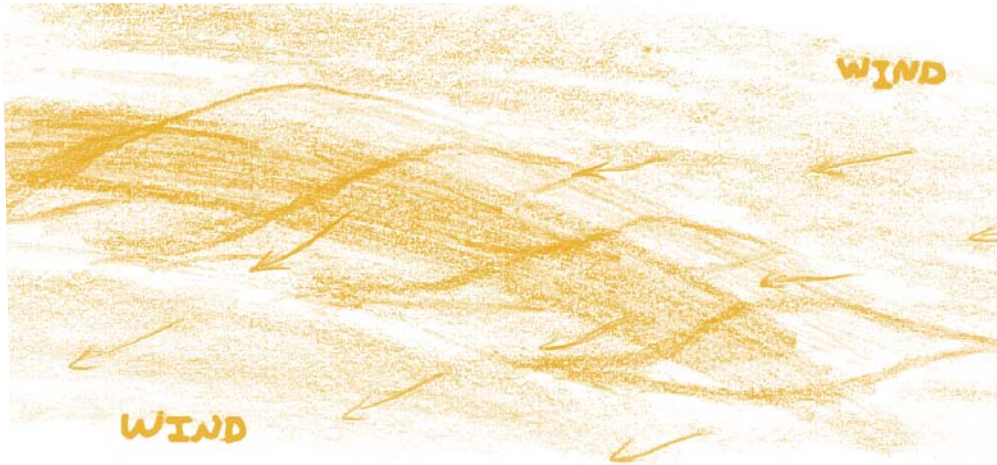


Figure 2

The cloud's only motion is its waxing and waning in vertical and horizontal thickness. At times, it is about a mile across, while at others, it shrinks to a quarter-mile across at most, with some gaps opening up along its length. Similarly, the thickness undulates from 1000 feet thick of dark gray to barely a wisp of white or white-gray. The most lateral movement one sees in this form is an extended hand's width over the sun, and then a retreat back.

As a class, we spend about 30 minutes under this sky, observing what we can of our shadows in the 5-minute breaks of sunlight. Thereafter, we return to Main Lesson for its final half-hour. After assigning the homework, the class is off to snacks, while I venture out to resume my observations on this lenticular cloud which has paid a visit to the Capitol area. But alas! The cloud has disappeared. It has not migrated downwind or upwind, as an inspection of the northwest or southeast horizons shows; rather, it has vanished. As an observer, I feel great regret, for I have failed to capture the cloud's disappearance in the act. This is not the first time I have let the escape of such a cloud to go unnoticed. There have been many other opportunities, but a quick trip into a bank or grocery, and I have missed the ultimate disappearing act of the lenticular cloud.

Six weeks after this early November observation, a family of lenticular clouds visits the Washington, DC, area. On December 11, I am again at the Washington Waldorf School. There has been another dramatic change in air masses – yesterday was rather mild and humid, with light winds from the southwest; already today, the wind has shifted through the west to the northwest, and it feels as though the air is drying out. A very cold night is on the way. There are low-level (below 10,000 feet above the ground) cumulus clouds moving at very high speeds from northwest to southeast. High above are cirrocumulus clouds (above 20,000 feet) moving from west to east, also at very high speeds. At the middle levels (approximately 10,000 to 15,000 feet) are more of these stationary ribbon-shaped clouds. Today, instead of one grand cloud as we saw on November 3, there are at least five, and they are parallel to one another. Two of these are at least 6 miles long and a half mile wide; three others are at most 3 miles long and a quarter mile across. All of these clouds are again airfoil-shaped in cross section, although they are a bit thicker and stouter than those on November 3, see Figure 3 on the next page.



Figure 3

This is a Saturday, and because my work for the day is self-scheduled and mostly complete, I am going to stay outside and watch these clouds. See Appendix #1 for a photo of some lee-of-range clouds similar to those in this viewing (to be included in the next issue).

One such cloud near the west horizon, and south-most of this family of clouds, is particularly active. In a matter of about 5 minutes, I watch it shrink from a 3-mile by one-quarter-mile, 1000-foot-thick French bread-shaped cloud, to a 3-mile wisp, at most 100 feet thick. Over the next five minutes, it swells up again, nearly attaining its original shape and size. It shrinks again, rather slowly, and then swells again. Never does it move horizontally, and never does it roll or twist; nor does it show any signs of vertical (convective) movement. As on November 3, there are no protuberances from this cloud. Nearly all of the surface appears frog skin-smooth. This cloud is simply materializing and then dissipating in place.

I watch the waxing and waning of this cloud through 3 cycles, and wonder whether the cycle will break. So often have I missed the final dissipation of these clouds. This one commences to dissipate again, but this time more rapidly. In less than a minute, it has totally vanished. It has not been pulled apart; nor has it boiled itself upward; nor has it rained itself out. Rather, it has simply de-materialized, starting from the edges and eating towards the cloud's center in front of my eyes, no more than 4 miles away. One lengthwise edge re-materializes for half a minute, and then disappears a last time. I watch for 10 minutes more, and the cloud never re-forms. This time, Houdini has boldly performed his trick without my even turning away.

As it has become a cold evening, I quickly go inside for warmer clothes, then resume my outdoor post as observer. The other clouds are still there. An hour more of observation shows the vanished one never to appear again. Its brothers and sisters stay where they are, another of these smaller clouds disappearing rapidly – this time once in a one-to-two minute period, never to reappear. The others stay in their places, in spite of the lower cumulus and upper cirrus clouds moving rapidly by. I retire to indoors but check the sky periodically for another two hours. The lenticular clouds never move – but after about 2 hours, they are gone entirely. The upper level cirrocumulus and lower level cumulus linger on for 2 more hours, after which it is time for bed. I awaken the next morning to a cold, clear day.

The lenticular clouds this afternoon and evening have a striking luminosity of appearance. As I am viewing them, the sun is low in the sky, and horizontally about 30 degrees southwest of the clouds, as measured from me as the angle's vertex. Unlike those that appeared on November 3, these have a glowing sheen to them, resembling mother-of-pearl. Their color is a wintry white-blue that one might associate with glacial ice.

Lenticular clouds form rather infrequently over the DC metropolitan area. One is unlikely ever to see them in the summer. With the first strong cold fronts of autumn, one sees them occa-

sionally, perhaps once to twice a season. The winter months produce them the most frequently – sometimes twice a month if the weather pattern is actively changing between arctic air masses and more moderate weather. They appear most commonly after intense coastal storms that so often bring behind them strong Polar or Arctic winds from the north and northwest. During the springtime, they become less common once more, visiting the DC area only once to twice a season. Throughout the Washington, New York, Boston, Portland (ME) metropolitan areas, their seasonal frequency is similar: many appearances in the winter, some in spring and fall, and few in the summer. The farther north and closer to the mountains one moves, the more frequently the lenticular clouds appear. In Boston and Portland’s summer season, for example, they appear nearly monthly, while in DC, three months can elapse with no sightings at all. In these coastal areas, they frequently resemble long ribbons or waves, their long axes forming perpendicular to strong winds. The sightings reported above were typical for the Washington or New York area.

B: Lenticular Clouds over Northern New England’s Mountains as Seen from the Valleys, 10 to 20 Miles Away

Late October, 2003, Meteorology Main Lesson at the Lake Champlain Waldorf School, Charlotte, VT (about fifteen miles south of Burlington). What has been a gloomy, gray month of October has, overnight, turned into the vibrant orange, scarlet, fiery yellow, green, and deep blue celebration of color for which New England autumn is so famous. The fog has moved out, in favor of a strong cold wind from the northwest. The sky is mostly clear. All around the high country, one can see the first deposits of the season’s snow. The higher upslope one looks, the more solid the white. In the valleys, we are a mere 1000 feet in elevation from the grip of winter. Even in the low country, the wind is strong and gusty.

Over many of the mountain tops are space ships. The War of the Worlds is on! On its white steed, Meteorology rides in to rescue us – the space ships are mountain clouds.

Out my bedroom window in Hinesburg, 10 miles east of school, I see the Mount Ellen-to-Mount Lincoln range quite clearly, about 10 miles southeast of Hinesburg. This 9-mile range runs as a wooded knife-edge from north-northeast to south-southwest, and rises to just over 4000 feet in elevation from the valley floor, some 3000 to 3500 feet below. Above this ridge’s highest peak, Mount Ellen, there hovers one of these flying saucer-shaped clouds. It is slightly elongated, following the length of the ridge. However, one is struck by the overall horizontal roundness of this cloud, especially at the northern and southern reaches of it. The cloud is hovering around 1000 feet over the top of the ridge, and is approximately half as high again as the mountain range. This cloud measures about 3 miles in length, and 1 to $\frac{1}{2}$ miles across, see Figure 4.

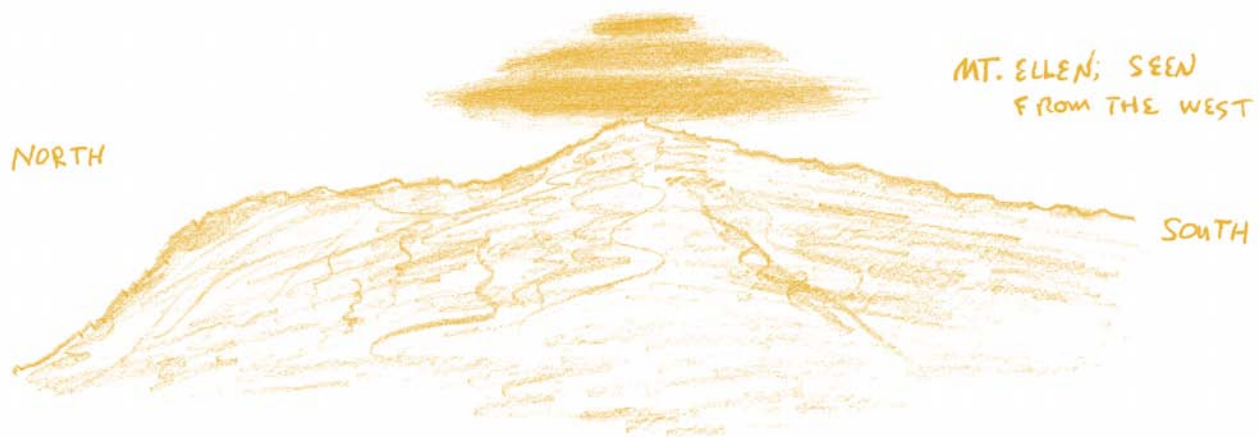


Figure 4

In cross-section, one can see great detail. This cloud resembles an airfoil. It is slightly concave upwards on the bottom, seeming to allow space for the ridge to be seen from below. It is more rounded, convex, over the top. It has several layers that are stacked one on another. The edge of each layer is very sharp, tapering off to nothing, as the cutting wheel on an electric can opener. See #2 in the Appendix for a New Hampshire photo of similar clouds (coming in the next issue). This cloud stays in place. Even though the wind is reported to be howling over the mountain tops, and even though an occasional cumulus cloud floats quickly overhead, this cloud keeps its position over the mountain. It appears to cut the air like a wing, and looks similar in cross-sectional character to the Washington, DC, cloud mentioned previously.

After admiring this sight for twenty minutes over breakfast, I go in to shower. Ten minutes later, I look out the window and find the cloud has disappeared. Houdini is up to his old tricks. On the way to work this day, I drive along a country road that has views of the Green Mountains and the Adirondacks. Many of the mountains have lenticular clouds above them. Some drape over mountaintops themselves, but most are several hundred feet over the summits. None of these clouds moves, in spite of the strong winds blowing in from the northwest. There are scattered fracto-cumulus in the air, and these are swirling and churning through the air, showing strong turbulence a few thousand feet aloft over the valleys. There are no high-level clouds to help the observer to spot what the winds are doing aloft. Unlike the Washington, DC, area, Northwest Vermont does not lie beneath a heavily traveled airway, so there are no contrails to watch, either.

This morning, I arrive to open up the school, which entails about twenty minutes of indoor work. By the time I finish, the sun is shining on snow-covered east faces of the Adirondacks that face down on Lake Champlain and the school. Most of the lenticular clouds have vanished. By the time Main Lesson begins, the only ones remaining are so far away to the north that one can not observe them for any great detail.

Over the course of the winter of 2003 to 2004, there are many displays of lenticular clouds. I never catch the disappearances. Frustration!

C: Lenticular Clouds over Northern New England's Mountains as Seen from the Mountain Peaks, within Yards of the Phenomena

In early March of 2004, I go to Mount Ellen for an early spring snowshoe up from the valley. The day is mostly clear, with some high thin stratus clouds. It is relatively warm for March in Vermont – 20°F in the mostly snow-free valleys, and not much colder at the summits, where the snow is still 4 feet deep. The wind is howling west to east over the tops. It is around noon, and it is still mostly clear. The sky above alternates between clear blue and the milky white of high stratus clouds. With the direct sun, it feels quite warm, but under the cover of even the thin clouds, the chill is very apparent.

The neighbor's yellow lab and I slog clumsily southward through the deep snow. Along the ridge, there are many fallen trees to negotiate. During one such adventure lasting no more than 5 minutes, I am distracted from my concentration on the sky. I look up, and no more than 100 feet overhead, a lenticular cloud has formed! No wonder it is cold! Although the cloud is thin (one can see the sun's shape through it), it is blocking out nearly all warming from the sun. Southward along the ridge, I see that this cloud is very small, and localized to the top of Ellen, where I now stand. Most of the ridge is cloud-free, but about three miles south is Lincoln summit, also under small lenticular cloud.

The Ellen cloud forms and dissipates rapidly, over and over again, never fully vanishing, but also never fully materializing. Sometimes, it creates a large, upside-down dish with a thick rim that extends out 1000 to 2000 feet laterally west from the summit. See Appendix #3, (in the next issue) for an idea of what I was seeing here from the inside. At such time, the cloud overhead remains quite thin, but the rim appears to thicken and darken. This is likely a matter of perspective, as when looking up, I see through only 100 to 200 feet of condensation, while in seeing horizontally, I look through 10 times the distance of the same. At other times, the cloud is merely a thin wisp over the mountain. At all times, the cloud bottom is no more than 200 feet above; at times,

it is possible to reach it with a snowball. I throw a few upwards into the cloud, and as the wind pushes each snowball's initially vertical flight strongly to the horizontal, I can see cloud between me and the snowball! Never is the cloud more than 100 to 200 feet thick. When the rim develops outward, it sinks to just below the line-of-sight to the horizon.

One can see movement in the cloud. Although its overall form is stationary, as so many of these lenticular clouds I have observed before, the internal 'fabric' of the cloud seems to act as a conveyor belt, flowing with the wind over the mountain top, roughly parallel to the topography. I see cloud streaming over the mountain at speeds as high as the day's strong winds. The cloud's composition is not perfectly smooth as it has so often appeared from below; rather it is subtly blotched. This is what reveals the cloud's rapid inner motion to me, the viewer.

Atop Mount Ellen, it is freezing cold, and I cannot stay long. On the way down along the ridge heading north, I look back from time to time. The cloud continues its thickening and thinning. It disappears in a moment while my back is turned. On the ridge below the summit, the trees are thicker, and the wind is not as strong as it was on Mount Ellen, half an hour before. But I have no way to tell whether the wind has diminished on top as well. This causes me to speculate whether subtle differences in the wind's speed or direction can cause these clouds to form and to dissipate: Were lower parts of the ridge cloud free because the wind there is not as strong as it was on top? Or was the wind over the whole range strong as it was on top of Ellen? Many visits to mountain ridges have told me that the wind is often dramatically stronger at the actual peaks. Hikers already coming down to lower parts of a knife edge often admonish me to put on a wind breaker – that it's cold and windy a mere furlong up the ridge.

D: Other Observations Involving High Winds and Localized Cloud Formation

1. A Vapory Tornado

In May of 1986, a television helicopter doing severe storm reconnaissance spotted and filmed a tornado from a vantage point of a mile away, at an altitude of some 2000 to 3000 feet above ground. This tornado tore a path over agricultural and wooded land. As it touched down upon trees, it flicked them upwards with such speed as to make them appear to disobey Newton's First Law: Trees came up more like flecks of pepper attracted to an electrostatically charged comb than the massive things which trees are, being blown somewhere by mere wind. No matter, a startling appearance on this tornado video was how the funnel materialized and disappeared, over and over again, over parts of its length, through the duration of the one-minute video. The dance of the funnel was chaotic in form and gyration. It twisted, contracted, expanded, and whipped about along its length from cloud to ground. By contrast, one could see the track of destruction in the trees kept a fairly steady direction and speed. Sometimes over this track, there was no visible funnel, while at other times, the tornado was a looped and twisted rope of cloud. At still other times, there was the classic tapered shape of a funnel cloud.

Parts of this tornado appeared and disappeared in a manner resembling the appearances and disappearances of lenticular clouds. It was not visible at all times – it sometimes vanished and then quickly reappeared, only to quickly vanish once again. When visible, it was smoky white. There appeared to be only one source of smokiness, but a source so small as to be clearly insufficient to have created the whole massive smoky funnel. This source was a small patch of fog that instantly was forming and being sucked into the funnel. At the ground, there appeared to be no dust or water source – only the small (150 feet long by 20 feet across) area of fog. The tornado was only occasionally attached to the cloud. The storm's spin sped up and slowed down over the whole funnel and also over various parts of it. In places, the funnel was contorted, and its movement resembled that of a snapping whip. In the funnel, the appearance and disappearance of the cloud happened in a flash and seemed to be related to quick changes in wind speed or direction.

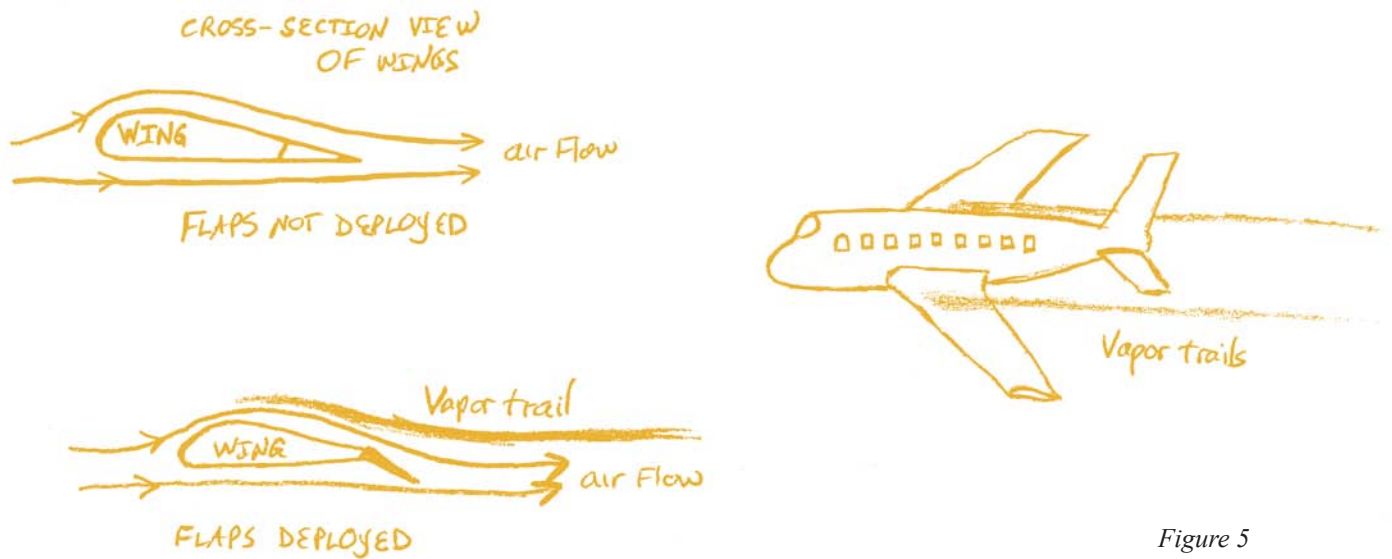


Figure 5

2. Cloud Trail over the Wing of a Landing Passenger Plane

On an April 1995 return to the Washington, DC, area, I took a flight in a DC 9 (no pun intended). The weather in the DC area was soggy that morning. There was light rain and drizzle, and the cloud ceiling was no more than 1000 to 2000 feet above the ground. The temperature was around 50°F. As this was one of my first flights to what was then a new home, I was watching out the window for nearly the whole flight, whether the view was landscape or under-cast below. Upon approaching the DC area, we descended into the clouds. I watched out the window, not expecting to see anything but gray enveloping the plane. Within a few minutes, we were descending below the cloud layer, a few miles up the Potomac, on final approach for Reagan National Airport. At about 1000 feet above ground level, the pilot deployed the first increment of flaps. As I watched this happen along the wing, a thin vapor trail appeared over the top of the root (closest to the fuselage) of the wing, see Figure 5, above.



For the airfoil to maintain lift, it must cut through the air evenly, so that air going under the foil meets the same air that was immediately above the foil before the foil cut through. For this to happen, the air passing over the top of the foil (A to A') has to go a greater distance in the same time than the air beneath it (B to B'). The faster the air blows, in a Laminar flow, the lower its pressure.

Figure 6

As an airplane lands, it needs to slow down, so that it can land under control over the limited length of the landing strip. A tool for slowing the airplane is the flaps, which change the shape of the wing so as to add length to the air's trip over the top of the wing while keeping the length of the air's trip under the bottom to a minimum. This increases lift at low speeds by reducing the air pressure on top of the wing, see Figure 6. (This is not meant to be an exhaustive proof of how lift works. The Bernoulli Principle, like many discussions in physics, is the subject of much debate.)

In the instant case, when the pilot deployed the second increment of flaps, the vapor trail disappeared as suddenly as it had initially appeared. This was yet another observation of changing high winds and quick emergence and disappearance of visible condensation.

3. Banner Cloud on a Building During a Tornado's Passage

In 1991, the McConnell Air Force base in Kansas was struck by an F-4 tornado, packing winds estimated at 250 miles per hour. Some of the GIs at the base had a video camera trained on the funnel and the areas immediately- and soon-to-be impacted. The viewer can see the increase of wind by the airborne debris and the uneven shaking of signs, along with the ripples on water puddles below. As the wind field approached one of the barracks buildings, one could briefly see a banner cloud form at the top corner of one of the building's walls. This cloud resembled a tattered flag, worn to within a foot or two of its bunting, and extended along the length of the corner of the wall. Imagine the bunting extended along the corner of the wall and flapping in the direction of the wind, streaming in the wind's general direction.

Banner clouds form sometimes on the lee sides of very sharp peaks, like the Matterhorn, during times of very high winds, and they often persist for as long as the wind is present. In this case, the wind lasted only seconds, and the banner cloud proved ephemeral. (Fortunately, the tornado itself missed the barracks, sparing the lives therein.) This video gives yet another example of strong, quickly changing winds, and quickly forming and then disappearing cloud formations.

[To be continued in the next issue]

Homemade Audio Speaker for Grade Eight

Here's an exercise that I have found to be an excellent culminating activity for the study of electromagnetism in grade eight. Mikko Bojarsky demonstrated this activity at the Rudolf Steiner College's "The Art of Teaching Grade Eight" training session. Students can build an audio speaker out of a plastic cup, a ring magnet, some insulated copper wire, and packing tape. The construction is simple and only takes a few minutes. Once built, the speaker can be connected to a radio or stereo with the proper speaker connection jacks and the students can hear surprisingly high quality sound coming from their speakers. The kids love this project, and it provides a very simple example of using a fixed magnet and an electromagnet to create useful movement, and amazingly complex movement at that.

Equipment: A roll of 2-inch-wide packing tape, ring magnets, insulated copper wire, plastic drinking cups of the disposable type, masking tape, some pencils or 1-inch diameter dowels, a wire stripper, and a radio, stereo receiver, or boom box. I have used doorbell wire from the hardware store that is about 20-gauge. The plastic cup should have a reasonably flat bottom with some flexibility to it. The bottom of the cup should be at least as large as the outside diameter of the ring magnet. The 8-ounce size from the grocery store has worked well for me.

Procedure: Give each student one ring magnet, three feet of insulated copper wire, one plastic drinking cup, an inch or two of masking tape, and six inches of packing tape. One inch of insulation should be stripped from the ends of the wire. Have the students each bundle 8 pencils together (or use a one inch diameter dowel) and use the bundle as a spindle to wrap their wires around. They should wrap the middle section of the wires around the bundle 5 or 6 times, leaving the ends of the wires extending out from their coils at least 6 inches. Slip the coils off the pencils and use the masking tape to tape the coiled portions of the wire together so they don't unravel. Each student should have a tightly wrapped coil of wire (with 5 to 6 wraps) with a roughly 1-inch inner diameter and the two ends of the wire extending out from the coil by at least 6 inches. I try to make sure that the inner diameter of my coil is slightly larger than the diameter of the hole in the ring magnet, so that if I set the coil on the flat side of the ring magnet, the coil rests on the solid "donut" part of the magnet.

The students should set their plastic cups upside-down on their desks. Place the coil of wire on the bottom of the cup and then place the ring magnet on top of the wire coil. Use the packing tape to tightly affix the magnet and the wire coil onto the bottom of the cup. Connect the stripped ends of the coiled wire to some wire leads that have been connected to the speaker or headphone jacks of your radio, stereo receiver, or boom box. If everything is working properly, the students should be able to listen to a surprisingly high-quality sound coming through their homemade speakers.

As always, be sure to experiment with this before doing it with your students. The main challenge that I've run into is finding a music source that I could hook into effectively. The speaker jacks of my 25-year-old stereo receiver worked the best for me.

Discussion: It is important for the students to struggle with the mechanisms that allow their speakers to work so well. The varying electric current in the coiled wire (that is connected to the stereo) creates a magnetic field of varying strength that is attracted or repelled, with varying degrees of force, to and from the ring magnet. This attraction and repulsion causes the wire coil to push against, and pull away from, the bottom of the cup, causing the cup-bottom to vibrate, which creates the sound that we hear. Students who can grasp the basics of how a fixed magnet and an electromagnet can be used to create useful motion have gained a window of understanding into the world of electromagnetic devices. I have used this activity in combination with having the students build the very simple electric motor described in Roberto Trostli's *Physics Is Fun!* ("The World's Simplest Electric Motor" in the 7th grade section) as an instructive, active, and engaging way to cap off the electromagnetism section of the grade eight physics block.

MATHEMATICS AND NATURAL SCIENCE

A Reflection from the Viewpoint of Pedagogy and the History of Ideas

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Goethe and Mathematics

Goetheanism, as understood by Waldorf educators, is a comprehensive scientific method that shapes the approach for each specific scientific discipline. When we observe a class instructed along Goethian principles, we first notice that the students do without any mathematics at first; formulas and models seem to have no place in the early years of science education. A public school teacher would introduce relatively abstract laws right in the beginning, but in early Waldorf education these concepts appear first only in the form of images.

We can observe the same in Goethe's relationship to natural science – he never introduced any mathematical formulas to his reflections on the various natural sciences. For the most part his followers have stayed loyal to his approach. The question arises that if this lack of reliance on mathematical formulas is a core element of Goetheanism in general, would we have to abandon this approach if “formulas” were to be introduced? Waldorf education in particular would need to ask how long the Goethian method can be applied. For example, would the application of mathematics in physics classes constitute some kind of compromise, which again and again has proven to be necessary anyway in dealing with the ‘outer world.’ Well-meaning defenders of Goethe's approach to nature observation have at times stated this would be the case. Theodor Litt, for example, has taken a forceful stand for Goethe in his book *Natural Science and Human Development*, where he emphasizes the problems of mathematical descriptions of nature.¹ Those who try to understand nature through formulas, he says, curtail the field of sense experiences in an unbearable way, reducing rich quality to mere quantity. Compressed into mathematic formulas, nature grows pallid, gray, and distant from human experience. Inner and outer nature are no longer connected. Direct experiences are portrayed as deceiving, while on the other hand mathematically calculated “reality” has lost its experiential dimension, and with this loss, natural science is also losing sight of its most important goal, which should be a service to humanity and its position in the world. That is why Theodor Litt argues that Goethe was correct to exclude mathematics in the context of natural science. The experiential quality of observing nature must not be discarded in favor of a quantifying approach.

This argument would be convincing if the choice would in fact be between mathematics in the natural science or valuing sense experiences (qualities). One goal of this essay is to show that this is not actually a choice, even though it does seem to be a compelling argument when we consider practical cases, such as the doctrine of colors, which Litt also cites as an important example.²

Goethe himself most likely would not have agreed with Litt's line of thinking. He left us writings about mathematics that reflect a more differentiated view of the role of mathematics.

In his essay “about the misuse of mathematics,”³ he argues against alienating natural science (from human experience) by the overuse of a “self-indulgent mathematical approach.” This preference for (mathematical) formulas little by little leads to making formulas the main focus. An approach that was actually only meant to serve a purpose now becomes the goal itself, and the true intent is in no way served,⁴

However, he never meant to dismiss mathematics in general, but confesses that he holds it in high esteem, even though he was not proficient in it. “I hear myself taking an accusatory stand, as if I were an opponent or enemy of mathematics in general; but no one can esteem it more highly than I do, especially since it achieves just that which has been completely denied to me.”⁵

Goethe

Goethe envisioned the approach of natural science to first develop its viewpoints unencumbered by mathematics, and then to permeate the resulting insights with calculations: “Mathematics and Physics – they must be presented as separate (fields). Physics has to exist in pronounced independence so that it can seek to enter into nature and its sacred life with love, awe and reverence, quite unencumbered by concerns about the approach and achievements of mathematics. The latter discipline in turn has to declare its independence of all outer form and must pursue its own great ways of the mind and find ever-purer expression without being bound to the manifest world, without trying to benefit from it or adapt to it.”⁶

He even claimed to employing mathematical qualities himself, even though he admitted to never having used calculations in his branch of science. These qualities are imbedded in his method, whose stringency he tried to model after mathematics. Later Steiner also saw this as a great merit of Goethe’s approach; wherever the strictness of a geometric proof can be transferred to other fields of science, one can hope for a blossoming of science. Goethe himself may have been aware of that while still pursuing his studies on Spinoza, since he found Spinoza’s ethics patterned after geometrical expositions. Based on this methodical understanding Goethe probably would have agreed with the famous statement of Kant’s that each science is scientific only to the degree as mathematics dwells in it. Goethe gives expression to this consideration: “This thoughtful process of connecting step by step, or rather deducing one thing from another, can be learned from mathematicians, and even if we do not employ calculations, we have to proceed as if we were accountable to the strictest task master of geometry.

“The mathematical method due to its thoughtfulness and purity reveals right away when we lapse into assumptions, and actually its proofs are just intricate explanations of the fact that complex statements are based on simple, sequential steps which are correct and irrevocably logical and true under all circumstances. And therefore mathematical demonstrations are always more of an exposition and recapitulation than arguments.”⁷

Starting from these thoughts from Goethe we will now attempt to discover historical and educational approaches that led and lead to discovering mathematics in nature, and we will try to understand how these approaches could find expression in our time.

Entering the Field of Physics – to Stand in Wonder like Pythagoras

We Waldorf teachers generally start our first physics block with an artistic approach to nature, for example via colors. With colors it is possible to stay in a purely qualitative space that enables the twelve-year-old student to experience intensely through the senses and leads him into a struc-

ture which has geometrical aspects and yet rests completely in qualitative realms. Numbers do not play a role here. Within Goethe's perspective we are here still on a level where nature presents itself and finds order while separate from calculations and computations.

The next step, however, will bring us into the realm of numbers. Soon, maybe during the same block, elements of acoustics are covered. We reach a level parallel to the "astonishment of the world" of Pythagoras. We learn that he reached this level through his work with the Monochord. Studying the harmonies of sounds, we discover that harmonic sound is linked with whole number string proportions. Any unbiased human being can experience here what it means when we say that science starts with wonder. Today we may no longer be able to fully follow Pythagoras, who was so strongly moved by this experience that he declared the whole-numbered proportions to be the soul of the world, and he saw the harmony of the spheres themselves caused by these proportions. But his astonishment and wonder can be re-lived, yes, tasted again by the child. Kronecker's statement, "God made the natural numbers; everything else is man's creation,"⁸ can still be accepted in trust on this level. "Here is necessity, here is God!" (Goethe)

I would like to call this mood, into which the child enters with the study of whole-number proportions, the pythagorean mood. The children are immersed in it starting in the sixth grade and live in it for a while. This mood returns from time to time only in happy moments, mirroring the progress of humanity. There were many experiences of nature which revived the joy in whole number proportions. Remarkable scholars dedicated their work to this and were very fortunate enough to discover these proportions. I want to name here Döbereiner, a contemporary and friend of Goethe's, who discovered the triads⁹ among the chemical elements, and Balmer who revealed the spectrum of hydrogen towards the end of the 19th century. Both succeeded in uncovering laws in their fields related to natural numbers: the specific weight of the elements on one hand, the wavelength of the spectral lines on the other. They were viewed as outsiders, because their laws – even though not inaccurate – were not based on any theory – which is, by the way, also true for the Titus-Bode law regarding the distances of the planets to each other.¹⁰ The Titus-Bode law is today regarded as a curiosity which is not based on any physical natural law while resting on the natural numbers. However we can state rightfully that a pythagorean core is underlying the whole-number laws of Quantum Physics, which in this case enjoys full agreement of the guild of natural scientists. In brief, I want to give an outline of the pythagorean stream of thought that, to this day, is weaving through science.

Historically the initially harmonic sensitivity was followed by an upheaval. Irrationality was discovered, for example, the fact that for example geometrical proportions of length can not always be expressed as a proportion of natural numbers – they can be irrational, not just rational. This discovery brought tragedy into Greek thought – which felt a disturbance of its need for harmony. This discovery also brings – corresponding to age development – confusion and motion into the mind of adolescents during puberty. The geometric proof is inevitable: The simplest proportions of length, like the one between the diagonal and the side of a square – are not rational. The number that emerges instead – the square root of 2 – can be brought to a desired level of exactness, but can never be exhaustively expressed in numbers. There is always a remaining quantity, which can find no final expression. We do not completely grasp them with our presentation tools. By the way, the same is true for all irrational numbers. We must fully experience this dilemma in mathematics.

After this process the insight into a special aspect of beauty is particularly relieving, for example, the insight that the Golden Mean is an irrational proportion, i.e., approximately 1 divided by 1.62. But that means: by embracing the irrational numbers, we do not leave the harmony of the world, but experience it in a new way. From the Middle Ages (Fibonacci) to our times, researchers have not tired of exploring the proportions of the golden section in nature – with rich rewards: The leaf arrangements of plants,¹¹ the laws governing the angles of the rainbow,¹² the spiral structure of certain snail houses¹³ – they all strive towards the Golden Mean. They do not illustrate it with ultimate precision, but the golden section provides a sort of ideal goal for many natural phenomena.

When we stop to think here, we have left the pythagorean level, even though we are still close to it. We can still feel the wonder and astonishment resurge when particular numeric proportions are realized and illustrated in the world. While no longer focusing on whole figures, we can now turn to the special numbers. Mathematics still somewhat resonates with mystic experience. So was Kepler regarded as a mystic¹⁴ (and somewhat disregarded because of it), when he projected the thought of the five platonic bodies between the orbits of the planets believing that he was glimpsing the secrets of the world creator (see article by David Mitchell in this issue). Maybe we may pay homage to him by naming this the keplerian level. It corresponds as we have so far established, the experience that a ninth grader has of the world. If this stage is sufficiently integrated into the mathematical exploration of nature, we can be sure that the ninth-grade students will welcome our approach.

Phenomenon and Equation – from Aristotle to Descartes

In order to better appreciate the next step, it will be helpful to review the exploration of nature in antiquity. Aristotle is its most renowned representative. His writings on nature show an intense drive to collect experiences and to order them. For many years after his death, his system of the different kingdoms of nature – which he created nearly single-handedly – was unrivaled in its comprehensiveness. And yet he basically shunned the experiment as much as mathematical contemplation, if we disregard his study of the motions of celestial bodies, which study he regarded as mathematically penetrable. He described the earthly phenomena in their manifold manifestations just as he saw them and did not really derive natural laws from their appearances, as we are seeing them in recent times. For example, he noticed that all bodies in motion eventually come to rest if no outer impulse renews their motion. He regarded this non-activity as their natural behavior. It never occurred to him that it could also mean a repetition of a motion once it is initiated, since he could not observe such a phenomenon. As Weizsäcker once observed, Aristotle described the world as he saw it.¹⁵ That made it impossible for him to make much progress with a stringent mathematical approach.

Only after nearly two millennia has humanity reached a stage where we can make the step from phenomenological observation to abstract, mathematical understanding. Galileo is the great pioneer of this approach. He had to first thoroughly simplify the phenomena so that he could reach mathematically meaningful results. He shed all interfering experiential factors such as friction, air resistance, dependence of pendular sway from strength of initial impulse, and so forth. This allowed him to formulate simple laws, which can be expressed in simple equations. That resulted in new concepts, for example, that of inertia or force-free movement, which cannot be directly experienced; this process of simplification enables a distinction between a basic laws

and supporting conditions. Weizsäcker commented that now nature was described in a way that could no longer be experienced, and that it is precisely this approach that allows a penetration by mathematical thinking.¹⁶ It also gave rise to the impulse to modify the supporting conditions to conform to theoretical expectations. The conceptual way was now prepared for future technical development.

In Galileo we can notice how, at times, the exactitude of observation was compromised by the desire to arrive at simple relational laws. For example, he simplified the results of his pendulum studies in a way that leads us to wonder how many such experiments he actually conducted, even though he proudly asserted that he had done many. Perhaps we should not accuse him of untruthfulness, as some do, but recognize that he lived in a time when there was a new need to grasp the essence of nature in mathematical equations – a need that forcefully demanded to be filled.

This stage of development is reflected in the tenth grade student. His/her inner need is directed at the scientific conception of the world. He wants to experience practically how rational laws and outer reality coincide. Ideally he does not yet doubt science, but hopes that it can help him to truly understand the world. This need is wonderfully filled by Rudolf Steiner's physics curriculum for this grade wherein he suggests teaching the dynamics of projection and fall (ballistics) and to quite strongly emphasize it according to the inner mathematical law of the parable. One should implement this directive as clearly as possible, without any mention of side conditions, air resistance, etc., and an immediate need in the young person is satisfied. One could say: "The world can now be penetrated by the mind. What I formulated in my own mind directly corresponds to outer facts. Thinking and observing relate to each other as a key to a lock." Let us call this stage the Galilean-mood, which can be characterized thus: An unbroken trust in the power of mathematics in relation to nature. The power of mathematics does not stand in doubt if we cannot yet express a fact mathematically – that only indicates our own shortcoming.

The studies in cartography (surveying), which happen in most Waldorf schools during the 10th grade, correspond to this level (see Peter Glasby's article in this issue). The students experience how the geometry of landscape and environment can be mathematically expressed and find their conceptual hypotheses clearly substantiated as they transpose the results into a map, a geometric reflection of reality. Any desired level of precision can be achieved and is only restricted by technical equipment or one's own lack of diligence. Once the mathematical method is mastered, mistakes can be detected and corrected. Within a set context the students are able say with certainty, the world can be governed.

At this point in the curriculum the coordinate system in mathematics can be introduced more appropriately than ever before. Descartes once united geometry and algebra like that, and made a mathematical contribution to the sense of a reliable reference point in the manifest world, generated by surveying and cartography. So we will take the liberty to name this phase, which is characterized by an integrative awareness of nature and mathematics, not only after Galileo, but calling it the Galilean Cartesian phase.

Awareness of the Boundaries

We have to keep in mind that even a well-executed mathematical description of nature has a limited scope of validity. After the rather naïve Galilean phase, one must learn to consider the fringe conditions of one's actions. That cannot yet be the goal in the 10th grade – sowing doubt would be unhealthy at that level; the mood of "ignoramus et ignorabimus" ("we don't know and

we won't know")¹⁷ is quite detrimental as the youths wants to *make the world their own*. But in the last two years of school a methodical consciousness must be cultivated. It is therefore useful to re-visit in the 11th grade a relatively elementary law, the law of electric resistance by Ohm. We can now clearly point out the limits of the formula $U = I \times R$; it is based on an assumption of unchanging temperature conditions, which are so rarely encountered in real life. Similarly, we can direct attention to the limits of validity of all natural laws defined by their specific areas of applicability. Steiner alerts us to this fact and suggests we not talk about natural *laws* at all, but to develop postulates which later should be examined as to their area of validity.¹⁸

The study of global cartography shows the students that it is impossible to grasp reality in its fullness through simple and predefined laws: every attempt to depict the globe as a plane entails certain distortions that can easily lead to misconceptions (e.g., about the size of the continents). We must decide in all humility what type of incorrectness we can live with in any given case. Accordingly the various projections of the globe emerge, which we are obliged to discuss with the students.

Such insight into the limits of the methodology should not be confused with the doubt about the fundamental ability to grasp the world, which Steiner wanted to keep out of the education.¹⁹ Even if the map does not present a perfect image of the world, the globe is theoretically suitable for such a representation. The simple equation cannot encompass reality fully but thinking surely can achieve that and maybe also mathematics which keeps evolving. The arising doubt is justified here: we have to realize that the tool of mathematics has to always remain an instrument in the describing of nature, while we have to stay alert to not let formal thinking 'roll away' blindly (as Steiner warns).

This understanding can be achieved early in the 12th grade, and reflects the process of humanity towards the end of the 19th century. Earlier on, humankind felt exuberant confidence in the scope of mathematical methods. It seemed possible to cast a systemic and basically all-encompassing net of formula over the fullness of reality. Laplace was able to speak of a super-human intelligence that supposedly possessed knowledge of the present state of the entire world down to the most minute details and the respective motion of its atoms. This intelligence would mathematically hold the entire past and future of the universe with complete certainty.²⁰ This concept of the mechanistic universe (including the human sphere), however, could only be truly reached by his famous "Daemon." Likewise the young Max Planck was advised not to enroll in the academic discipline of physics, because supposedly this science was already completely mapped out.²¹ Everyone now knows how much the abrupt transition into the new century has revolutionized the natural science approach. Today no one speaks anymore of absolute certainty in the methodology of mathematics and physics. More prevalent today are the questions about the scope and validity of the currently dominant theories.²² But this pessimism in regard to our ability to know should not yet have to be experienced. Surely we have something more inspiring with which to close our school education!

The following thought may help us: the first centuries of the Galilean method were formed by a preference for linear natural laws. First is always the attempt to express the processes of manifest reality in the simplest equations possible. Not that nature proceeds only in a linear fashion, rather, that these equations can at least be mastered and integrated as a whole. That's why they were applied wherever possible. This approach however predetermines its own solutions. If nature did not fit into these equations – too bad for nature. Of course non-linear natural laws

have been known for a long time – e.g., the law of mass attraction. But it is not possible to integrate such laws into a unified whole. Therefore solutions can be approached only in small steps, and can only be approximate. Before computers, thoughts around the principle of the solution had to suffice. Now that the task of detailed computation has been transferred to a machine, much has become possible; the practical results in space technology is a case in point.

The work with non-linear natural laws has resulted in the end of an era in which the Laplace ideal of the “Daemon” had its valid place. Such equations reflect behavior that is termed “chaotic” in recent times. That means if we make step-by-step calculations according to their rules, even smallest divergences can have unexpectedly grave effects. When we start with nearly identical initial situations, the tiny divergences can cause radically different results. But since we can never determine the initial set of experimental conditions in absolute detail, we basically can no longer make any statement about the later behavior. We know this from attempts at mathematical weather predictions, and also from certain movement processes in the cosmos as observed in the planetary system. Non-linearity means that there are narrow limits to predictability. Accurate prediction of results becomes so impossible that any result soon seems imaginable. It can lead so far that the results of the mathematical endeavor randomly disperse among widely varying areas. The calculations of chaos theory have generated aesthetically pleasing computer images that have been widely carried by the media. These images are, however, not actually the result of intense thought processes, but reflect a rollout of computations with the help of a machine. But one such result was already validated before the computer era: the pioneer of chaos theory, the French mathematician Poincaré, discovered that the planetary systems need a certain form of chaos in order to persist. The proportions of the orbit cycle duration of the planets have to be irrational and by necessity they cannot be expressed in natural numbers. If this were not so, the regularly re-occurring encounters in space would have a destructive effect on the order of the system which would unhinge itself. In other words: The repetitive meetings of the planets would generate a “kick” such as we can observe when a child successfully moves a swing. Finally these “kicks” would exceed the bounds of the system and destroy it. Steiner highly valued this conclusion of his contemporary, whose meaning he interpreted as follows: in the planetary system there is always a residue of mathematical unpredictability – otherwise it would not continue to exist.²³ This remaining irrational factor is a guarantee of inner cosmic life.

The more powerful tools of our time could give more depth to this insight. The proportion of the orbital cycles must not only be irrational, but within that irrationality various levels of stability occur. One of the “surest” proportional numbers lending stability to a system is that of the golden section! Therefore, as we are living in a stable world, this proportion should be found somewhere in the planetary systems. Even the sober scientists who came to discover this felt reminded of Kepler who had ‘integrated’ the golden mean everywhere in the planetary system by introducing his platonic bodies which are largely governed by the golden section. The newly discovered model seems like a late justification of the great astronomer. The previously described facts are only a partial result of more modern mathematics, but it is symptomatic if presented in the appropriate context. After long and winding detours, a numeric law, which came to our attention because of its aesthetic implications, has regained its honorable place. Now it is recognized as a determining factor of a natural system. The mind of a 12th grader is soothed by such views.

We can add something more to the development we just described. The approach of math-

ematicians and reality could not yet succeed fully as long as there was the attempt to represent nature in the most simple – if possible linear – equations. To say it with a picture: A complicated curvature will hardly be able to follow a straight tangential line for long. But if we can improve the convergence factors, for example by finding a suitable adaptive curve, we can stay true much longer to the actual line parameters.

We are challenged to make mathematics so intrinsically flexible that it does not lose touch with reality. Non-linear thinking constitutes a first step on this path. One must surely proceed further and must re-think many parameters – that means supposedly fixed auxiliary factors – recognizing variability where one would prefer to keep them constant. Then mathematics, which wants to follow nature, may perhaps no longer limit itself to the inorganic realm, but can encompass the various forms of life. That has been realized here and there, but as a whole, is rather an intention than a program. A student in the senior class may also be inspired by a challenging task that is worthy of engaging his or her lifelong dedication and work. Admitting that personal achievement is not yet reached does not equate cognitive pessimism. Resignation only sets in if we believe that we never ever can realize that to which we aspire. The increasingly complex, but fruitful and expandable, relationship between nature and its mathematical description causes no such resignation.

Mathematics as the Practice Ground for Something Higher

Goethe wanted to make mathematics and related fields of study the benchmark for methodically precise work. When dealing with true science, “one would have to be accountable to the strictest geometrician.” In this spirit we should be able to practice mathematics as a training ground so we can safely progress in other fields that are free of sense perception. After all, mathematics is increasingly being applied to aspects of nature, an activity of pure thinking, far from the senses. The more modern pioneers of mathematics have conquered realms in which common sense perception no longer suffices. It is amazing that the completely non-applied systems of thought of someone like Riemann could already be put to use in the last century, only a few decades after their introduction, when new ways of thinking were also emerging in physics.²⁴ The general theory of relativity is based on the thoughts of this “abstract” mathematician. The mental bond between pure thought and sense interpretation that fascinates the 10th graders shows its effectiveness in a historical perspective again and again.

With a seminal thinker like Riemann, we can hope to gain from the insights that he coined in the spirit of mathematics, but also pertaining to other fields outside of his own subject area. Such thoughts were found in his legacy of writings, even though they were not meant for the public eye. The reader must evaluate if these thoughts are mere speculation or logical thoughts beyond the limits of sensory perception. Riemann wrote: “The general laws of ballistic motion, summarized in the introduction to of Newton’s principles, are caused by their inner state. Let us try to draw conclusions according to this analogy within our own inner awareness. Continuously new idea fields emerge that rapidly pass through our consciousness and disappear again. We observe a continual activity of our soul. Each action is based on something permanent that makes itself know on special occasions (through memory) without permanently influencing the various forms of consciousness. With each act of thinking something permanent enters our soul that has no lasting effect on the outer world. Every act of our soul is based in something permanent that enters our soul with this act but simultaneously leaves the world of form completely.

“Lured by this fact I pose the hypothesis that the universe is filled with a substance that continuously streams into the ponderable manifest atoms. Both hypotheses can be replaced by this one: ponderable atoms are the gateways where substrates of the corporeal world continuously pass into the spiritual world. The substrate disappears into the atom because of the spirit/mind substance that has been formed there immediately before this passage; the ponderable bodies accordingly are the place where the world of spirit reaches into the world of form (corporeal world).”²⁵

Does this open up a view into an etheric world of life forces as Steiner described it: a reality that borders our physical world from above? Or is this only a form of materialistic monism? ²⁶

Notes

1. Litt, Theodor. *Naturwissenschaft und Menschenbildung (Natural Science and Human Development)*, Heidelberg: 1959.
2. As so-called secondary sense qualities.
3. Goethe, J.W. von. “About Mathematics and its misuse as well as the periodic governance of the different scientific disciplines,” Volume 2 of the *Papers on Natural Science*, Stuttgart: no year.
4. Ibid.
5. Ibid.
6. Goethe, J.W. von. “Sprüche in Prosa (Sayings in Prose),” *Papers on Natural Science*, Volume 4, Stuttgart: no year.
7. Goethe, J.W. von. “The experiment as a mediator between subject and object,” *Papers on Natural Science*, Volume 3, Stuttgart: no year.
8. A mathematician of the 18th century.
9. An ordered system in the area of specific weights of the elements that was later expanded into the periodic system of the elements.
10. According to this law the sequence of distances between the planets and the sun can be expressed in exponential values of 2.
11. Realized by the botanist Braun in the 19th century.
12. Compare the description by Walther Bühler, *The Goetheanum*, yr 67, nr. 11, 13.3.3, 1988.
13. Doczi, Gyorgy. *The Power of Boundaries*, Capricorn, 1978.
14. Kepler, *Mysterium cosmographicum*.
15. Weizsäcker, C.F.v. *Die Tragweite der Wissenschaft (The Scope and Effects of Science)*, Stuttgart: 1966.
16. Ibid.
17. Du Bois-Reymond, 19th century.
18. For example in “Fundamentals of a Theory of Cognition” in *Goethe’s World View (Weltanschauung)*.
19. Compare “Three Lectures on Public Education” in GA 192.
20. In his treatise on probability theory.
21. Planck, Max. Collected lectures.
22. Compare this with the work of Karl Popper.
23. In the third course on Natural Sciences, GA 323.
24. Bernhard Riemann, 1826–1866, mathematician.
25. Riemann, B. *Gesammelte mathematische Werke und wissenschaftlicher Nachlass (Collected Mathematical Works and Scientific Legacy)*, Leipzig: 1892.
26. Monism means the explanation of the world as caused by one single – e.g., the material – principle.

– first published in *Erziehungskunst*, 1992, issue 6/7

Animal Sight

The eagle, the vulture and the buzzard perceive the movements of the objects of their prey from astonishingly great heights and distances, distances quite beyond the scope of the human eye. They see the movement and not the animal itself. Should the animal stop suddenly (freeze), the bird of prey could not see it. This suggests that the eye of the bird is specially attuned to perceiving movement. It also suggests that the eye of the birds of prey is constructed differently than that found in other animals or in the human being. They have as a protrusion, an immensely enlarged blind spot. Dr. E. Menner of Halle gave some information about this at the Zoological Congress held in Stuttgart in July 1935. He had found that in a camera, if the plate was replaced by an opaque piece of glass and a small disc placed in such a way that the image of flying swallows was obscured by it, he was able to see a secondary image of the moving birds on other parts of the glass.

The perception of movement happens in such a way that the picture of the moving object appears on the edge of the field of vision and moves right off it. With an enlarged blind spot, the disappearance can be centripetal as well as centrifugal: the image disappears into the blind spot and reappears on the other side of it. So an object moving along the diameter of the field of vision of a bird of prey will have four points of perception: one on the periphery, one on the side of the blind spot, one on the other side where it emerges, and a fourth at the periphery again. In the eye of these birds the blind spot protrudes so far into the cavity of the eye that it throws a number of shadows on to the retina. This causes the retina to be surrounded by a shadow rather like a much serrated wheel. It gives a great multiplication of the points of perception and they are integrated like the tiny pictures of a moving film. This discovery is most important. not only because it explains the high degree of accuracy of the sight of these birds, but even provides some additional knowledge of the human faculty of sight and proves that we have, besides the static perception, a second mechanism for sensing moving objects.

It helps explain why the perception of color is most intense in the center of the field of vision and fades out, the closer the object moves to the periphery. The faculty of sight is concentrated in the center of the field of vision and becomes ever more hazy the closer the object moves to the edge. This might be thought to be a defect, but now the reason for it is clear. The more the faculty of seeing the object recedes, the clearer is the perception of its movement, and similarly where the sphere of the perception of the senses ends, in the field of uncertainty, a new perception for dynamics appears. The eye is our teacher, even for the whole of human psychology. We concentrate on perceiving the physical world with our senses and our consciousness, but some parts of our inner life are like the blind spot to the faculty of vision. This is not a defect, but opens up a new kind of perception for that world of forces which always works behind the world of actualities appearing to the senses. For this reason, it may be true that the eagle flying up to heaven opens our mind to the World of the Logos.

Kepler's Model of the Universe

by

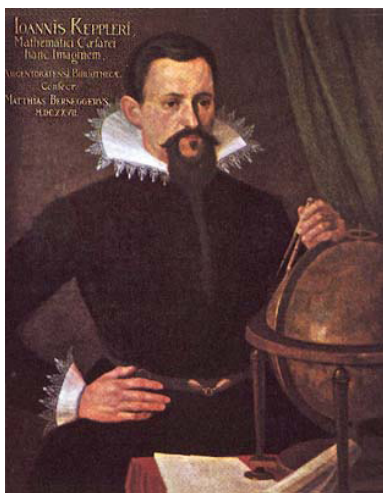
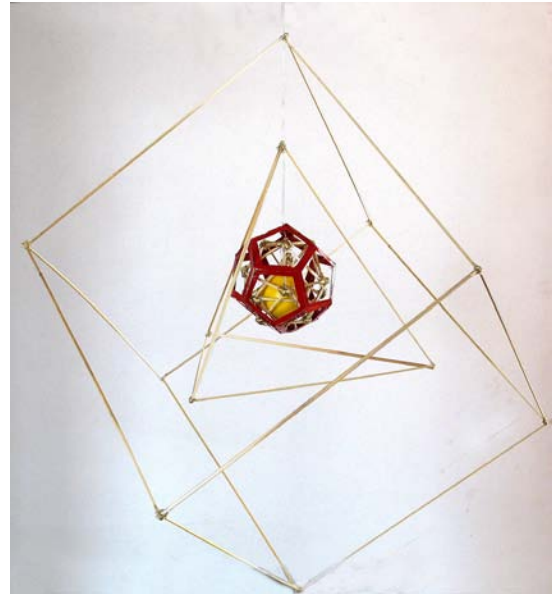
David S. Mitchell

In the early 1970s, while reading Rudolf Steiner's biography, I became intrigued with his description of the role of geometry in shaping his spiritual path. Always drawn to the subject, I found myself reconsidering it in a new light with regard to the development of thinking.

Being a person with practical interests, I was intrigued by the metamorphosis of forms and began constructing models. One of the first was the umstülpbare Würfel (reversible cube) conceived by Paul Schatz, then came an equilateral triangle that transformed into a working model of Pythagoras' Theorem. However, it was while digging for beautiful tetrahedral calcite crystals in a small stream in the Jura Mountains of Switzerland that a deepened understanding of the Platonic Solids was gifted to me.

A dear friend, a Waldorf teacher living in Basel, Switzerland, shared with me Kepler's accurate dimensions for building a mathematical model of the planets based on the Platonic Solids. I would like to share this scaled-down model and its construction with other teachers.

I have constructed the form with students in grades 7–9 and, while it requires some skill and a lot of patience, it can bring delight along with a much deeper understanding of Kepler and inner qualities of the Tetrahedron, Hexahedron, Octahedron, Dodecahedron, and the Icosahedron.



First, let's take a look at Kepler and his intentions. Johannes Kepler (December 27, 1571–November 15, 1630) was a key figure in the scientific revolution. He was a German Lutheran mathematician, astrologer, and astronomer best known for his laws of planetary motion, based on his *Astronomia nova*, *Harmonice Mundi* and the textbook *Epitome of Copernican Astronomy*. Kepler was an assistant to the infamous astronomer Tycho Brahe; he was court mathematician to Emperor Rudolf II, mathematics teacher in Linz, and court astrologer to General Wallenstein. He also did fundamental work in the field of optics and helped to legitimize the telescopic discoveries of his contemporary Galileo Galilei. He is sometimes referred to as “the first theoretical astrophysicist.”

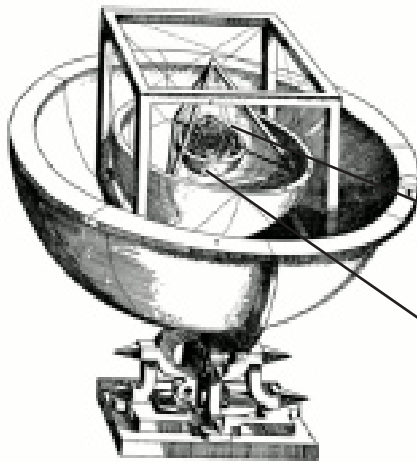
In 1596 Kepler published *Mysterium Cosmographicum*, or *The Sacred Mystery of the Cosmos*, which contained his attempt to relate the distances between the orbits of the solar system to the five Platonic Solids by alternately inscribing them and circumscribing them in a set of concentric spheres. Here is a selection in his own words explaining the relation between the planets and the Platonic solids:

“Before the universe was created, there were no numbers except the Trinity, which is God himself... For the line and the plane imply no numbers – here infinitude itself reigns. Let us consider, therefore, the solids. We must first eliminate the irregular solids, because

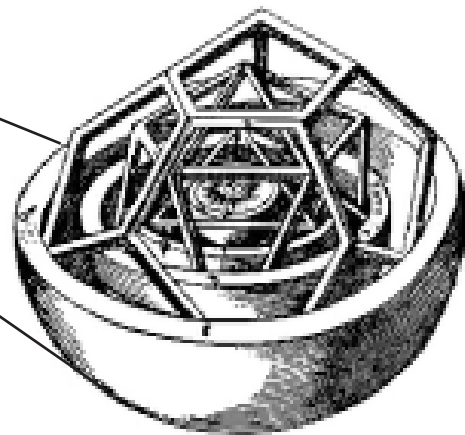
we are only concerned with orderly creation. There remain six bodies, the sphere and the five regular polyhedra. To the sphere corresponds the heaven. On the other hand, the dynamic world is represented by the flat-faced solids. Of these there are five: when viewed as boundaries, however, these five determine six distinct things – hence the six planets that revolve about the sun. This is also the reason why there are but six planets (sic) . . . I have further shown that the regular solids fall into two groups – three in one, and two in the other. To the larger group belongs, first of all, the Cube, then the Tetrahedron, and finally the Dodecahedron. To the second group belongs, first, the Octahedron, and second, the Icosahedron. That is why the most important portion of the universe, the Earth –where God’s image is reflected in man – separates the two groups. For, as I have proved next, the solids of the first group must lie beyond the earth’s orbit, and those of the second group within. . . Thus I was led to assign the Cube to Saturn, the Tetrahedron to Jupiter, the Dodecahedron to Mars, the Icosahedron to Venus, and the Octahedron to Mercury.”

To illustrate his theory, Kepler envisaged an impressive model of the universe which shows a Cube within a sphere with a Tetrahedron inscribed in it; another sphere inside it with a Dodecahedron inscribed; a sphere with an Icosahedron circumscribed inside; and finally a sphere with an Octahedron circumscribed. Each of these celestial spheres had a planet embedded within it, and thus defined the planet’s orbit (see drawings below).

In his 1619 book *Harmonice Mundi* or *Harmony of the Worlds*, as well as the aforementioned *Mysterium Cosmographicum*, Kepler also made an association between the Platonic solids and the classical conception of the elements: the Tetrahedron was the form of fire, the Octahedron was that of air, the cube was earth, the Icosahedron was water, and the Dodecahedron was the cosmos as a whole or ether. There is some evidence this association was of ancient origin, as Plato tells of Timaeus of Locri who thought of the Universe as being enveloped by a gigantic Dodecahedron while the other four solids represent the “elements” of fire, air, earth, and water.



Kepler's Platonic solid model of the Solar system from Mysterium Cosmographicum (1596)



Closeup of inner section of the model

Directions

Materials: collected dry grass, card stock (or manila folder), UHU all purpose extra strong adhesive (or a hot glue gun), nylon-coated miniature wire cable 7 strand .018 diameter from Cable Strand Corp, 2660 Signal Parkway, Signal Hill, CA 90755 (or monofilament fishing line), wax paper, 3/4 inch diameter wooden or Styrofoam sphere, small brass screw eye, yellow watercolor paint, red spray paint, a small bottle of gold paint and a fine brush or Q-tip.

Procedure:

1. For each model obtain several one-foot or taller pieces of straight, yellow straw from a field. Cut off the seeds and husk the outer covering.

2. Using the template on page 31 or by measuring, cut and stockpile the requisite lengths on a sheet of stiff cardboard.

3. Using the template for the Dodecahedron on page 32 transfer the form onto a piece of cardstock (old manila file folders work well) using a piece of carbon paper, a ruler, and a #2 pencil. Or scan the template into a computer and print onto cardstock the quantity you need. Or photocopy the template onto cardstock. Glue the two halves of the Dodecahedron together as shown in the illustration below.



4. When cut out the Dodecahedron can be spray-painted red to represent Mars.

5. Paint the ball (representing the sun) yellow, affix the screw eye, and tie the wire or monofilament line using a fisherman's knot.

6. Tear off a piece of wax paper and assemble each of the solids using the layout indicated on page 31. Use an extra piece of the grass to carefully apply the UHU. Allow it to dry and repeat the procedure with the next solid.

7. Return to the dry flat forms and carefully release them from the wax paper (anything other than wax paper will drive you mad!) Now, carefully form the Platonic solids beginning with the Octahedron encasing the sun. Tie it off so that it rotates freely and is centered in the Octahedron.

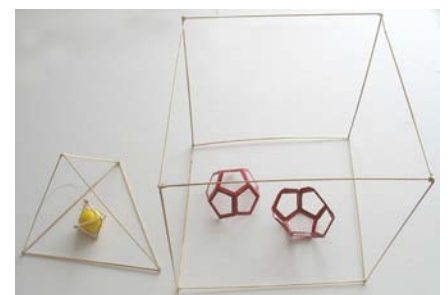
Construction hints:

Note: For all forms use as little glue as possible. If gobs of glue are unavoidable, then apply a touch of gold paint when they are dry.

a. The Hexahedron (cube): on the wax paper create two squares. Allow the glue to dry. On one square affix the four vertical arms. I find it convenient to have four glass drinking glasses or jars. I stand and tape them with a strip of masking tape next to each vertical member. When the glue has dried I tip it over and reverse the process by gluing the form to the bottom square.

b. The Tetrahedron: on the wax paper create an equilateral triangle. From each corner extend an arm so that it meets in the center above the equilateral triangle. Glue and allow to dry. [An alternative is to use the schematic on page 31. As you assemble you will be required to cut away duplicating arms.] I like to begin with the Hexahedron and the Tetrahedron because they are the easiest and help make the fingers nimble for the more difficult forms to follow.

c. The Octahedron: on the wax paper create a square and glue the corners. From each corner extend an arm such that it meets in the center above the square. Allow the glue to dry. Affix an arm to each of the opposite points on the square but do not glue their tips together yet. Allow the glue to dry. Insert the sun with the wire or



monofilament and then bring the tips of the Octahedron together and glue. Allow the glue to dry. Now suspend the sun in the center of the Octahedron and tie it off at the tip.

d. The Icosahedron: use the schematic on page 31 to lay out the grass arms on wax paper. Fingers must be clean, dry, and free of glue. Carefully apply glue with a separate four $\pm$ inch grass “brush” to every union of the arms. The glue must be applied so that it touches across every grass arm to effect a bond. Allow the glue to dry. Gently lift the glued form from the wax paper, have small scissors at hand, and bend the form around upon itself and glue. At this point you will encounter *duplicate arms* that *will need to be cut away with the scissors*. Do this and then glue one end of the Icosahedron together. Allow the glue to dry. Insert the sun and Octahedron through the open end of the Icosahedron and then glue it shut.

Now suspend the sun and the Octahedron in the center of the Icosahedron and tie it off at the tip.

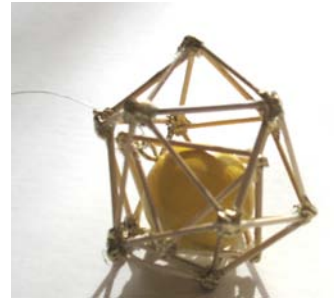
9. Take the sun, Octahedron, and Icosahedron and place it centered in the cardboard dodecahedron. Glue together the tabs of the Dodecahedron. (I find a hot glue gun does this quickly, but be careful not to get burned.)

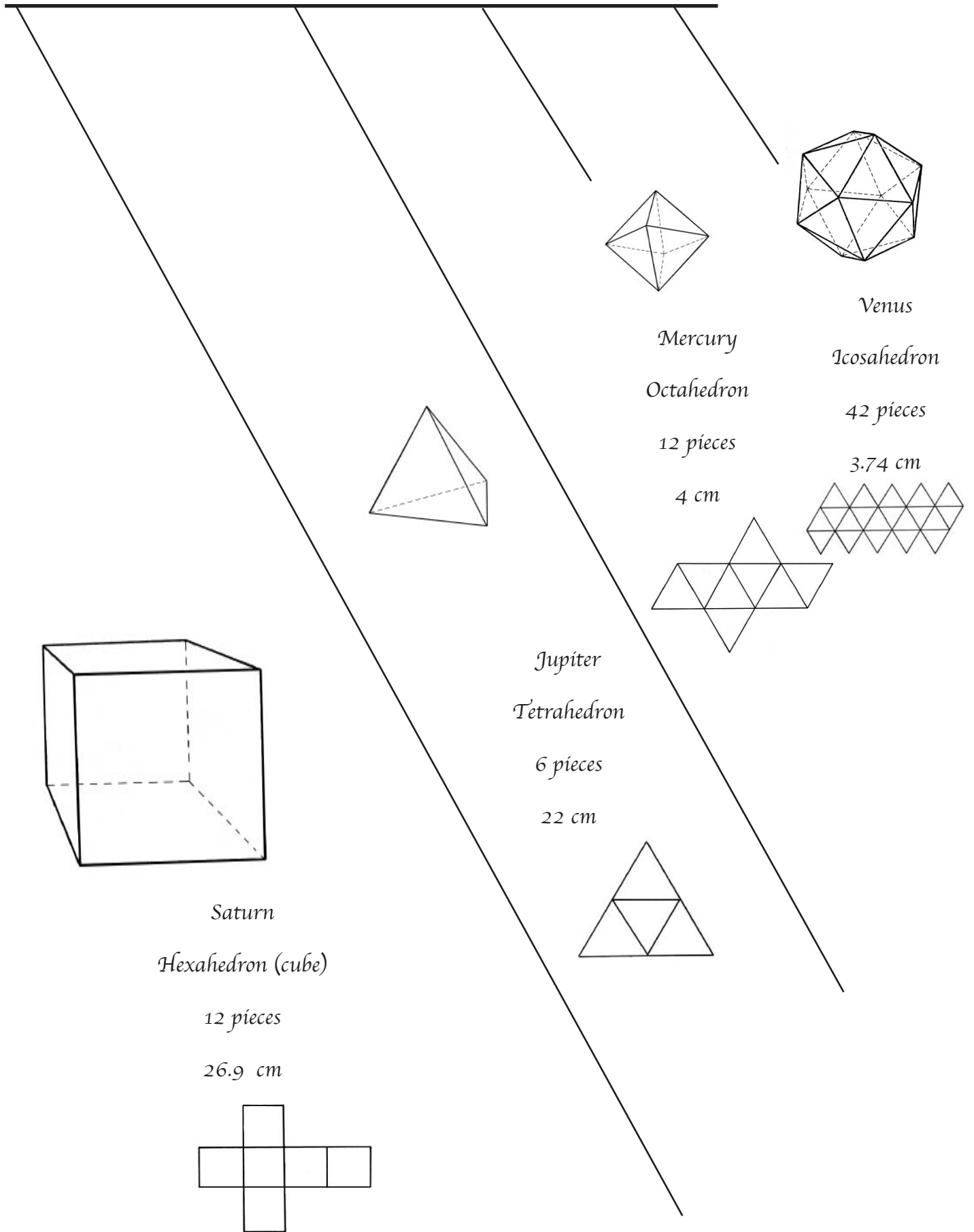
10. Suspend #9 in the center of the Tetrahedron.

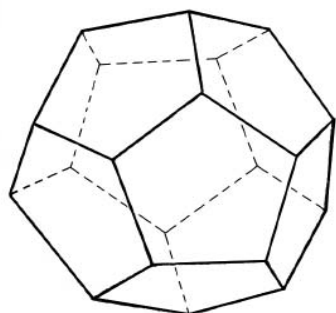
11. Suspend #10 in the center of the Hexahedron (cube) and hang the entire model from the ceiling with a thumbtack.

Now, imagine this form rotating around the earth and you have Kepler’s geocentric model of the universe and through this his imagination of creation and God, whom he considered to be a divine mathematician.

Final Note: *Teachers preparing this project for a class must first build a model by themselves so that they can have a tactile experience of the difficulties.*





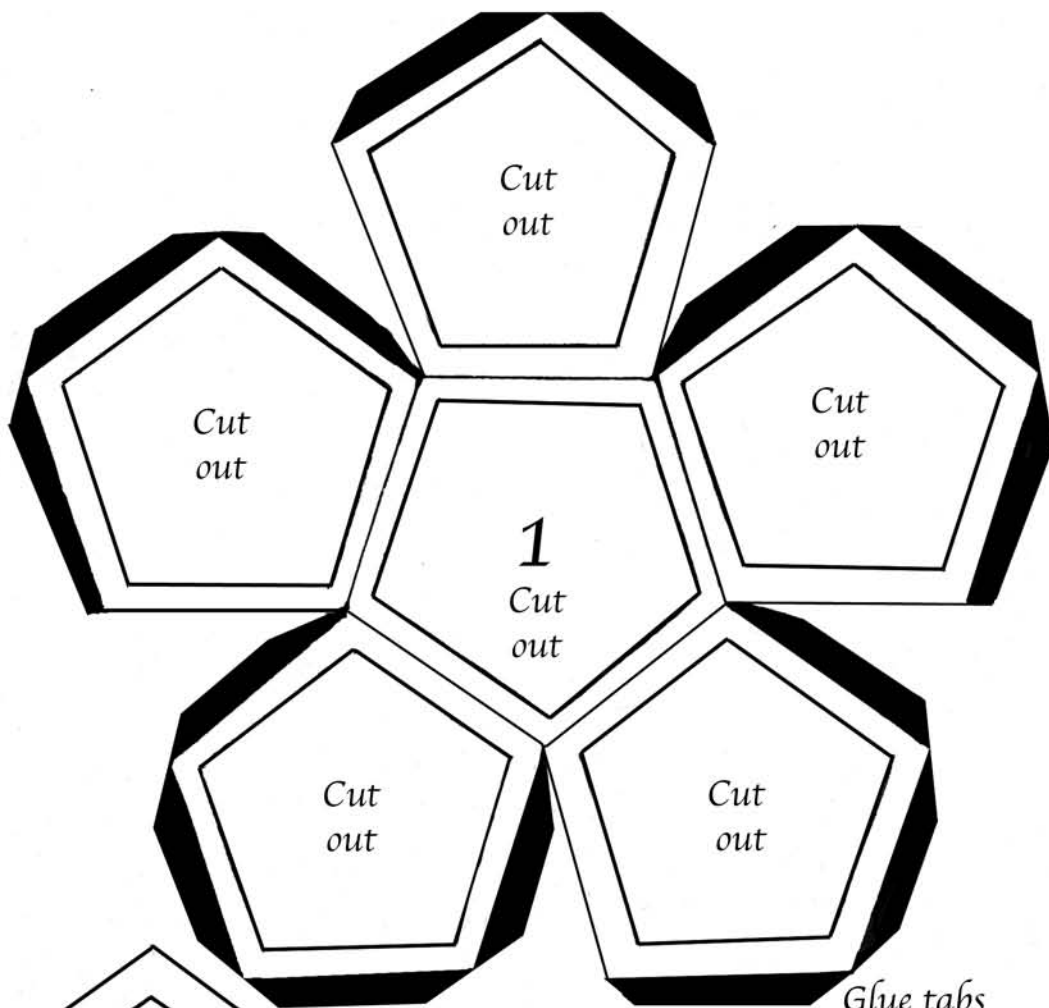


Mars

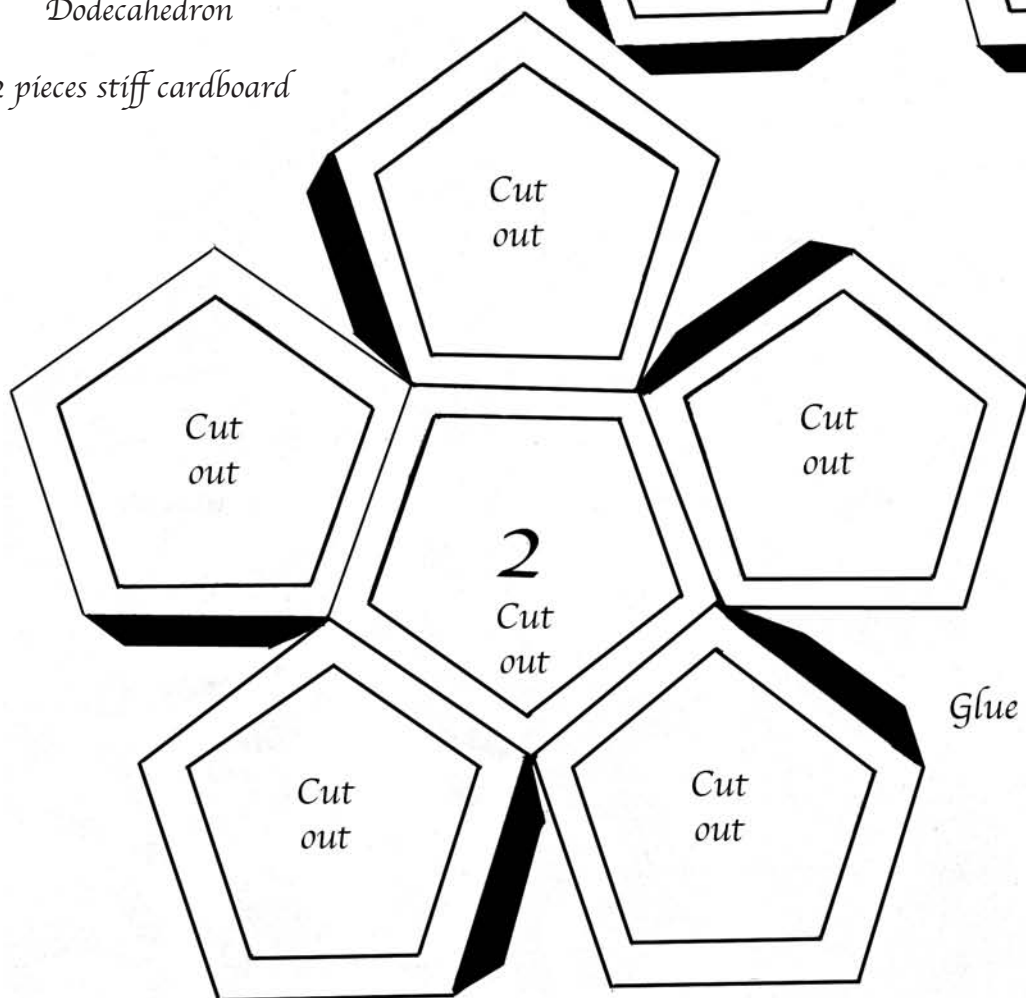
Dodecahedron

2 pieces stiff cardboard

Glue tabs



Glue tabs



Glue tab

Teaching Sensible Science



If the group above appears happy it is because they have just completed the first full series of “Teaching Sensible Science,” a course for 6th, 7th and 8th grade class teachers sponsored by the Research Institute for Waldorf Education and AWSNA.

Two years ago the AWSNA Delegates requested Douglas Gerwin and David Mitchell to come up with a new method for re-training teachers already active in the classroom. Soon Michael D’Aleo, Gary Banks, Lilli Anton and Barbara Richardson had the task in hand.

The course was founded on the principle that good science teaching requires more than a list of topics and a “how to” list of experiments. One of the fundamental premises of upper-grades and high school teaching is that the students must learn to understand and make sense of their own experience of the world while also coming to understand the view of another fellow human being.

The aim of the course is to give teachers a living experience of finding meaning in the world through the unification of perceptive elements of the world into a conceptual whole. This is referred to as a **phenomenological approach to science**. Over the course of three separate one-week sessions, the teachers were given a deeper understanding of the foundation of knowing in morning lectures and discussions, combined with afternoon sessions running actual experiments and having the time to really wrestle with the relationships and conclusions that are found. Morning and afternoon artistic courses supplemented the more “academic” sessions and gave the work a richer context.

The key focus of this course was not to give the teachers a curriculum, but instead to give the teachers enough exposure, practice and understanding of phenomena-centered science so that they really teach the sciences “out of their own experience and understanding.” Unless a teacher is somewhat grounded in this approach, how can we expect the students to learn to approach the world in this way?

An informal canvass of the participants indicated that the program was successful. Now plans are being made to start a new series. The editors of the *Waldorf Science Newsletter*

strongly recommend that every Waldorf elementary school in North America participate in this course. The credibility of Waldorf education will rise when we are able to teach the sciences in the manner in which they were meant to be taught. Most of us were not taught sciences phenomenologically, and the teacher training colleges and centers are not able to give the time that the study requires. You might consider “Teaching Sensible Science” as an insurance policy for your school – plus it is a whole lot of fun. Just look at that pictures below.

The next cycle of “Teaching Sensible Science” will begin this summer and continue into the next school year. All three of the week-long sessions will take place at the Waldorf School of Saratoga Springs. Dates are:

- * Saturday 24 June - Friday 30 June 2006

- * Wednesday 4 October - Monday 9 October 2006

- * Saturday 24 February - Friday 2 March 2007 (provisional dates)

For details and registration, contact Michael D’Aleo at spalight@verizon.net. A detailed account of this program can be found in the Autumn/Winter issue of the *Research Bulletin*.



An Optics Demonstration for Grade Seven

This demonstration fits nicely into the optics curriculum for grade seven. It is easy to set up and will make a strong impression on the students. It was one of many demonstrations presented at the “Teaching Sensible Science” training sessions at the Saratoga Springs Waldorf School last summer.

A large pane of glass (ours was roughly 30 inches x 30 inches) is set up on four “legs” over a dark surface (1000 ml beakers can be used as legs on a black table top). An object (a ceramic coffee mug works well) is set on the glass and the students look for the mug’s reflection in the glass. The students should observe that as their viewing angle gets lower, the reflected image becomes clearer. With the students looking at the reflected image, a second mug, identical to the first, is moved underneath the glass and positioned so that it fits precisely into the reflected image of the first mug. This is an impressive demonstration of the identical appearance of the reflected and tangible images.

This experience can also be used to raise students’ awareness of their presumptions about what is “real” and what is not. With only one ceramic mug placed on top of the glass, we see two mug images, one in “reflected space” and one in “tangible space.” The teacher can ask the question: “How many mugs are there?” Many students will say that there is only one mug, even though they see two mug images. When pressed as to why there aren’t two mugs some students will say: “Because the reflected mug isn’t ‘real.’ ” “Why isn’t it ‘real?’ ” the teacher might ask. “Because you can’t touch it, or fill it up with water,” the student might say. The teacher can then ask if everyone in the class sees two mug images. Hopefully, everyone will say, “Yes.” Then the teacher might say, “So, our visual experience of the two mug images is similar. The difference is that one of the mug images can also be experienced with our sense of touch, while the other cannot. We have a tendency to say that the image that we can touch is the ‘real’ one, and the other is ‘not real,’ but is this really an accurate way of describing our experience?” This can lead to a discussion of other visual phenomena that cannot be experienced tactilely, such as rainbows and holograms.

B. A.

Chemistry Challenge for Grade Eight

Here's an excellent way to challenge your eighth grade scientists. A colleague of mine used this activity as a final test during her 8th grade Chemistry block.

It is based on an activity described in Mikko Bojarsky's book, *A Demonstration Manual for Use in the Waldorf School Eighth Grade Chemistry Main Lesson*. It appears on page 38 of my copy and is entitled "Testing Milk as a Mystery Substance." If you don't have the book already, you should get a copy because it is an excellent resource. The specifics are well laid out in the book; however, the gist is that Mikko describes how to separate whole milk into curds, albumen, whey, and fat, and then test them for the presence of simple sugars, starch, protein, and fat.

Rather than treat this exercise as a whole-class demonstration, my colleague separated the milk into the different substances before class began. She then grouped the students into teams and gave each team samples of the different "mystery" substances. Their assignment was to test each substance and determine what type of food (simple sugar, starch, cellulose, protein, or fat) was present. Because my colleague had followed Mikko's book for her whole block and had done a lot of hands-on activities, the students were familiar with the methods for testing for the different food types. Nonetheless, this challenge required the students to develop their own experiment procedure, follow it systematically and carefully, and document their results accurately and objectively. My colleague was very happy with this activity and would do it again.

B.A.

On Being an Insect

by

John Davy

Insects concern the farmer and gardener intimately, and though these notes are written from a zoologist's-eye-view, they may be of some use in enlivening the farmer's-eye-view.

"The insect is provided with an exo-skeleton." This, almost the first sentence in entomological textbooks, means that the insect is hard outside and soft inside. The vertebrate is the other way round, a hard core surrounded by soft tissues.

It is interesting to consider the consequences of living, as it were, inside one's skeleton. For instance, the skeleton must be burst and discarded before growth is possible. But as soon as the epidermis is exposed to the air, it starts to form a new exo-skeleton which, when hard enough, hinders further expansion. One has the impression that throughout the larval and nymph stages of insect growth, a dramatic struggle is being waged between vegetative forces which cause the creature to eat, expand, increase its soft tissues, and burst its skeletal bonds, and hardening forces building and rebuilding a horny prison, a many-jointed, mechanical, marvel of increasing strength and precision and perfection. The adult form is reached when the hardening forces achieve final victory and the vegetative forces are unable to burst out of the skeleton. Instead, they transfer their activity to the reproductive organs. The insect becomes mature, and in the fertilized egg the battle can begin again.

Modern insect physiology has discovered a remarkable interplay of glands and glandular secretions which are intimately bound up with the opposing forces of growth and hardening, and confirms in great detail the above picture.¹

The muscles of the insect are attached to the exo-skeleton. When it molts it must detach its muscles, and re-attach them to the new skeleton—for a short time in between it is almost completely incapacitated. The insect is in a way dependent for movement on something which comes from outside itself (i.e., its outer skeleton, which forms at the surface of the epidermis and is hardened by the air). When the human being moves a limb, he feels that an impulse arises somewhere inside him and travels out into his limbs and into the world. The anatomy of the insect seems to suggest that its movements are an end-result of a process originating outside it.

Insects have compound eyes. If one tries to imagine what it would be like to have five hundred eyes (or even five), it becomes clear that it would be impossible to "pay attention" to the image presented by more than one of them at a time, unless they could all focus on the same spot, which insect eyes do not. One would either have to consider one image at a time – a laborious procedure if there were five hundred of them – or one would have to swim in a sea of images without "paying attention" to any one of them. The insect cannot shut its eyes or move them, and so has no control over the images that shine into it. It is thus very difficult to imagine an insect "looking out of" its compound eye. The structure suggests rather that such eyes exist so that the world can look into the insect.

Rudolf Steiner often spoke of the close connection of the insects with the plant world, and orthodox zoology remarks how the plant and insect have evolved hand in hand. The laws of

metamorphosis found by Goethe to lie behind the growth of a plant from seed to flower can be followed in the growth of an insect from egg to butterfly. But the close connection of the two goes further. The plant is given up to its environment; it is almost wholly dependent on the forces of nature outside it—rain, wind, sun and earth. And up to a point the insect is in the same position, as some of the phenomena above seem to indicate.

However, Steiner also speaks of the animal world as being distinguished from the plant world in being the seat of what are loosely called “desires “ or “emotions.” When an organism becomes “sensitive,” it enters the animal kingdom. Steiner described the forces producing sensitivity as “astral forces.” In the skeleton of animals these forces can in a way express themselves as form—perhaps one should say as frozen movement. For example, in the skull of the wolf its eternal hungriness is frozen into the bony form of its jaws; in the limbs, nostrils and ribs of a horse’s skeleton, the creature’s way of life, moving swiftly over the earth filled with air and movement, lies clearly sculpted in bone. In the insect, too, the hard skeletal parts express the nature of the animal: the savage jaws of the wasp and the hypodermic accuracy of the aphid’s mouth-parts; the tank-like almost metallic outer wings of the beetle, and the flower-like wings of the butterfly in which the hard, dry substance almost dissolves into light and color. But whereas in the higher animals the astral forces work from inside the animal outwards, the insect has its skeleton as a hardened instrument of astral forces which work from outside into it.

Steiner sometimes described the constantly moving air into which light plays from above and water from below, as a kind of material image of the astral forces in the world. In the relationship which creatures have to the air it is perhaps possible to see their relation to these forces. The higher animals draw air into themselves by means of their own breathing movements, and only through these movements can it penetrate in to the whole body; later it is given out again after the animal has for a time made it its own. But in the insect the air penetrates into the innermost regions of the creature through the tracheae-small pipes, which are a sort of ingrowth of the skeleton. It is impossible to feel here that the insect itself draws these pipes, and thus the air, into its body; rather, it seems that the same forces which form and harden the skeleton from outside, force their way right into the soft tissues of the insect, and the path they take is mapped out in the innumerable minute tubes which penetrate the whole body.

The higher animal seems to have a certain inner life of its own, a soul-life one could say, which is to some extent independent of the forces outside it. The seat of the insect’s soul lies among the elements through which and in which the astral forces of the whole earth organism play. The soul of the insect is, so to speak, outside it, and, like the soul of the plant, belongs among the natural forces working in wind and weather.



Surveying and Mapping

An Attempt to Integrate New and Emerging Technologies into the Class 10 Curriculum

by

Peter Glasby, Anthony L. O’Flaherty, and Dennis V. Millar

Summary

The following article describes an attempt over the past three years (2003–2005) to modernize the Surveying Course taught at the Mt. Barker Waldorf School, by adding to the traditional surveying triangulation techniques, the use of global positioning satellite (GPS) technology and the use of computers and the Arc Map 9 mapping software. In the process of describing the project, it is necessary to show some of the detail for the use of the Arc Map 9 mapping software; however, the descriptions are not exhaustive and are not meant to be read as a course in the use of Arc Map.

There is a description of how the new technologies have been integrated with the older methods and an evaluation of how the integration has worked from a pedagogical point of view.

Introduction

Surveying has been an important and memorable part of the Class 10 curriculum at the Mt. Barker Waldorf School since 1986. The part it has played in the integration of various aspects of the curriculum was described in an earlier article (Glasby and Millar, 1999). In those days, the University of South Australia was still teaching, as part of its surveying course, the use of optical instruments. In field practice today, surveying technology has changed considerably. The use of total stations, electronic levels, GPS, remotely sensed imagery, survey software and cartographic applications has relegated many of the spatial data acquisition and mapping techniques to use by traditional surveyors or educational establishments.

These changes led us to begin discussing how we could modernize our own teaching of the subject. We quickly realized that many of the modern techniques, though efficient and highly advanced, are educationally questionable due to the pushbutton technology approach whereby students would largely be taught to follow instructions, much like a recipe, with very little thought or insight into the process. Having ourselves used a modern total station, we realized that, wonderful as it is, the user could simply become a technician carrying out a sequence of steps for which no understanding is required. A comparison of triangulation using a total station to using a traditional optical theodolite will perhaps demonstrate the pedagogical advantages and disadvantages.

The total station user turns the telescope and focuses on the mirror (reflector) that is being carried around the landscape and then executes a measurement process by pressing a button. The results of slope, horizontal and vertical height distance, for example, are then transferred to an electronic notebook from where they are downloaded to a computer for processing. The processes of triangulation and computation are hidden from the user in the programmed electronic operations of the machine. Furthermore, specialist skills are required to operate survey software for the processing of total station data prior to cartographic output. On the other hand, the optical theodolite user needs to understand the use of the triangulation grid as a scaffold to help reference the features being mapped. In setting up and zeroing the machine the user needs to understand that there is a protractor in the instrument that he is in touch with through the scales that he must also learn how to read. This reading of the horizontal angle scale is learned by moving the telescope around and watching the scale change. The locking of the scale for zeroing, the reading of the angles from a point on the grid, are all accompanied by body movements. This body movement as a basis for more abstract understanding is a fundamental principle of education in Wal-



dorf schools (Steiner, 1996) and generally promotes a more interactive learning experience. The subsequent comparison of results between different student groups and instruments gives the learner a first hand experience of errors, their origins and scope. The calculation of averages for the results and then the calculation of horizontal distances all allow a slow dawning of understanding to take place in a rich time space where the experiences of what the students are doing can grow.

We were unanimous in determining that the traditional methods are educationally superior in that they allow a greater grasp of the ideas and principles by demanding that the students learn new bodily movements, which actually complement the ideas. For example, the precision of the angle measurements are accompanied by the large arm movements of turning the telescope, followed by the fine

finger movements required for the fine adjustment of the angle while bringing the stadia hairs onto the trig point.

The whole process can be experienced out of the activity. Another example is the measurement of the Base line of the triangulation grid, where a series of steps in learning are required before the horizontal distance can be established: tensioning the steel band, clearing the line of measurement, learning how to use the theodolite as a vertical height measurer, use of Pythagoras law to convert the vertical height difference and the slope distance to a horizontal distance.

The fieldwork is a critical part of the process. It is equivalent to the experiment of a science lesson or the practical experience gained in making a chair. Here the task is not only to give the students a theoretical appreciation of the elements of surveying but, in accordance with deeper educational principles, to help young people to feel a greater connection to the place in which they live and how they can orientate within it and measure it. To take part in the process of measurement of the earth is to feel part of a tradition that has played and continues to play an important role in the social life of humanity. (Think of the role of the surveyors in determining the State lines of Australia or the establishment of the height of Everest in Nepal.)

So how can we integrate modern technology into our surveying and mapping teaching program without compromising existing pedagogical values? What could be left out and what could be included? We were keen to use the global positioning systems, remotely sensed imagery and modern cartographic tools within a computing environment as a way to include a rich learning experience rather than sacrifice valuable curriculum time to computers per se. The following briefly describes our attempt to incorporate these elements into the traditional surveying process. This article is not a manual for carrying out the whole process. Only some parts of the process have been described in detail so as to help the reader form a realistic idea of what was attempted.

Equipment Required

As class sizes can exceed 30 students in some years, the Mt. Barker Waldorf School has, over the years, secured enough surveying equipment to outfit working groups of three students. This includes optical theodolites, measuring tapes, compasses, maps, safety equipment and a variety of outdoor equipment. The school has also purchased handheld GPS units (additional units are borrowed when required) and enough laptops so that there were two students per computer. The laptops need moderate capability (Pentium II-III, 512MB RAM and 6GB HDD), enough to run a secondary school licensed version of ESRI's ArcView ArcGIS software. The ArcView ArcGIS software is one of the world's leading geographical information systems software applications, used extensively by governments, educational institutions and private enterprise for the management of spatial information and cartographic output, i.e., maps. There is also a wealth of educational material available for this platform on the internet.

The Surveying Camp in 2003 – the Start of the Project

In 2003 we embarked on an ambitious mapping exercise: to map a series of springs and their associated tufa terraces at a site along the Trezona Range in the Flinders Ranges, South Australia. The students arrived at a location in the Flinders Ranges, after a day's travel in a changing landscape from the gentle, cultivated rolling hills of Adelaide to the vineyard vistas of the Barossa, to the broad fields of the winter wheat south of Goyders line where already on the horizon mountains begin to emerge and the arid grazing lands of the southern and central Flinders emerge. On this occasion we went beyond this up to the center of the Flinders proper, where the ranges line up in north-south chains, rising above the plains. For some of the students it is their first glimpse of this landscape. The quarters are occupied with excitement and the first evening's work begins.

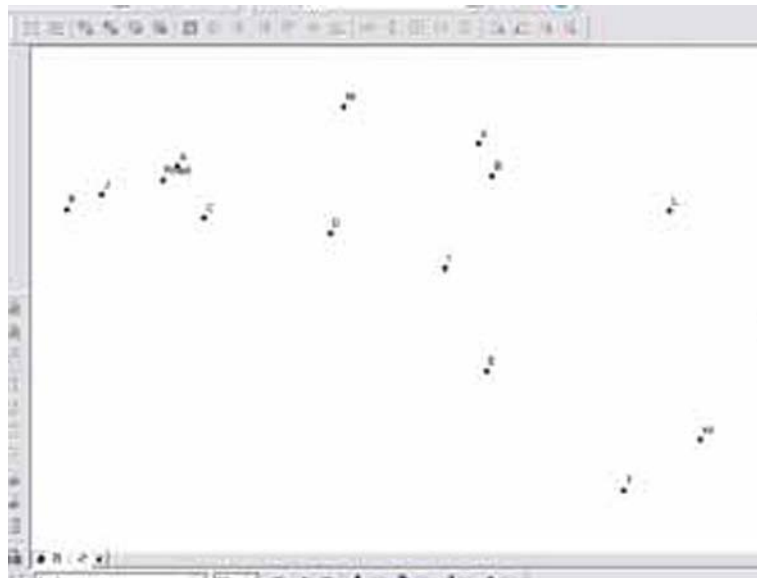
One of the first tasks for the students helped them orient themselves; i.e., gave them a sense of place. Firstly, the students were taught how to find direction using a simple watch. They were instructed on orienting the 12 to the sun; north is in the direction that bisects the angle between 12 and the hour hand. Students were also taught how to find direction at night by using the Southern Cross to find true south. An orientation to the geology of the ranges was also given on the first evening.

All the steps outlined previously (Glasby and Millar, 1999) were used again. In addition we had an aerial photograph (also in digital format) of the site and the surrounding area and a GPS allocated to each student group. The steps that we went through can be summarized as follows:

1. Orienting in the new environment: creating a mud map at first on the ground and then later more precisely on the aerial photograph;
2. Laying out a grid of Triangles with the students, which acts as a reference for more detailed mapping to follow. Pegs defining the triangulation matrix were hammered into the ground.
3. Angles between triangulation points were measured with extreme accuracy using optical theodolites. Geographical coordinates were obtained for each trig point by repeated measurements using GPS units.
4. One grid line length, the Base Line, was measured accurately using a surveyor's steel band.
5. The geographic coordinates were entered into a spreadsheet in Excel and then coordinates obtained for each of the points on the grid by using the "average" function of Excel.

These averaged points were then saved as a database IV file (*.dbf), which were imported into the mapping software (ArcGIS v9.0). The trig points when imported looked like this. This figure (right) is from the 2004 map at the stage of adding the Triangulation grid coordinates.

6. Detailed mapping of geological features, roads, fences, creeks and other distinctive features of the landscape was carried out using Tachometry. These hand-drawn images were then scanned into the computer and brought into Arc Map using the procedure described later below.



7. The Base Line was oriented to true north (the sun's zenith direction) by setting a theodolite up on one end of the Base Line, zeroing it on the other end and then tracking the sun until it reached its zenith. This gave the bearing of the Base Line. This step is still carried out even though the mapping software can automatically orientate the grid on the page to North.
8. To give an idea of the topography of the site leveling profiles were taken between chosen triangulation points, using a Dumpy Level, and the profiles were drawn, making repeated use of Pythagoras Law. These profiles were drawn by hand and then scanned and imported into the map layout.
9. Using the trigonometric Sine Rule, the lengths of all the other sides were calculated, a long and tedious task, especially at night after a long day's work.
10. Using the geographic coordinates obtained from the GPS average of one of the central trig points, the coordinates of all the other coordinates were calculated and compared with the GPS averages for the other trig points. These calculated points can also be imported into the mapping software and plotted, which gave a good comparison between the manual method and the straight GPS results.
11. Finally all the results were drawn up into the map. In previous years this step was done by each student on an A1 piece of plastic film, by first carefully drawing on the grid and then using this grid to hand trace the individual tacheometry drawings.

Importing Tacheometry Pictures into Arc Map



Prepare the Tachy sheet with clear drawings and make sure that at least three Trig points are drawn on the sheet. Scan the sheet and save it in the file where you are keeping all the data for your map.

The scanned sheet looks like this example to the left.

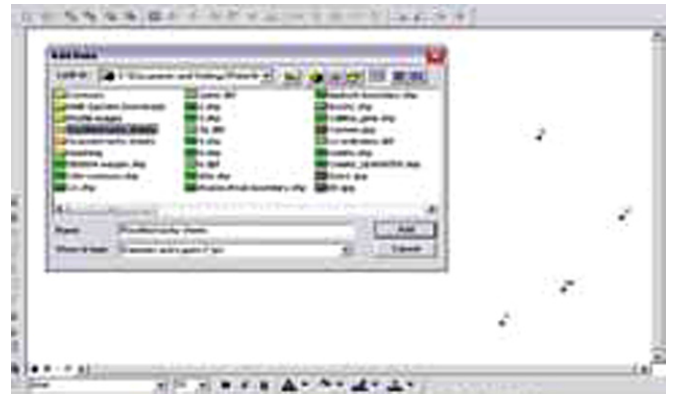
Make sure that all the tool buttons you will need are showing on the menu bars of Arc Map.

You may have to right click on the tool bar and click the tools bars down to "Editor." Choose the "Add" button from Arc Map and go to the file with the image. If it asks to build pyramids, say "No."

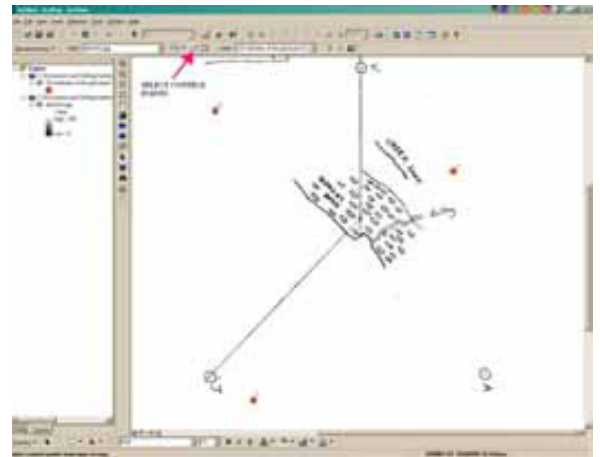
Zoom into the area of the Grid where you want to add the Tacheometry image with three Grid points drawn on it.

From the Layer menu choose the image you want to introduce.

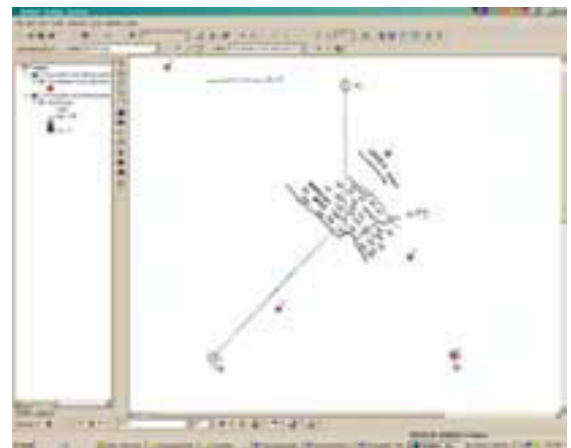
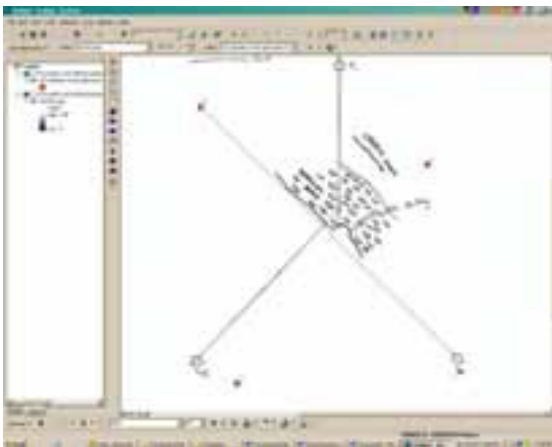
Click on the Georeferencing toolbar and choose “Fit to Display.” The scanned drawing appears within the Grid points but not yet aligned. It looks like this (right). Notice the Grid points on the drawing VAJ are not aligned with the coordinated grid points on the Arc Map screen.



Now use the the Georeferencing tool “Add Control Points,” shown with the red arrow. This activates the cursor to do the georeferencing. The drawn grid point, e.g., A, is selected and then the cursor is dragged to the Grid point A. This gives the drawn point A geographic coordinates.

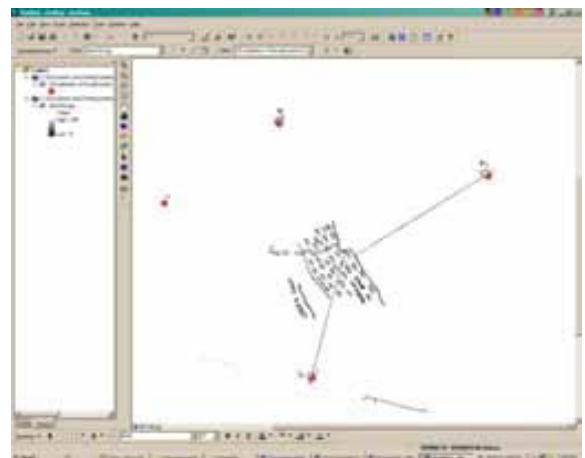


The picture adjusts one stage. It looks like this:



Repeat this for the remaining grid points and then press “Enter.” The scanned drawing then becomes totally aligned and contextualised to the geographic coordinates chosen for the map. It looks like this (right).

Notice how the drawn grid points are now aligned with the grid points of the map. A second drawing brought into the map in the same way will connect to all the other drawings in the right spatial relationship. These images are now called rectified images and can be saved as TIFF files and reused.



Extracting the Drawn Features in Arc Map

The next step is extracting the features of the drawings as shape files which are of three kinds: point, line and polygon. Trees are typically point shape files, creeks and roads are line files and areas of rock are polygon files.

Click the “Arc Catalogue” button on the upper bar.

Go to the folder with the data.

Right click in the folder. Go to “New” and then to “Shape file.”

For Line Data under “Feature type” choose “Polyline” and give it a name like “creekbank1.” Then click OK.

A new shape file called “creekbank1” appears. Left click on the folder and drag it into the Layers window of the Arc Map View or use the Plus button.

To add the feature to the Arc Map view: Highlight the new shape file in the Layers window; Click the Editor on the Toolbar and then choose “Start Editing”; On the Task Menu, choose “Create New Feature”; Make sure the Target is the shape file you are editing.

Zoom in on the area you are going to edit.

Choose the Pencil tool and click along the drawn line in the tachy drawing. Make the last click a double one to end the line.

In the case of errors: From the Task Menu choose “Modify Features.” The last vertex is automatically picked up.

Option 1: Go back to the last vertex, right click then “Options” to delete the vertex. Then left click to create a new one and double click to finish.

Option 2: Right click anywhere and choose “Finish Part.” Then you can modify previous mistakes by choosing the Edit arrow button and return the vertex to the correct position.

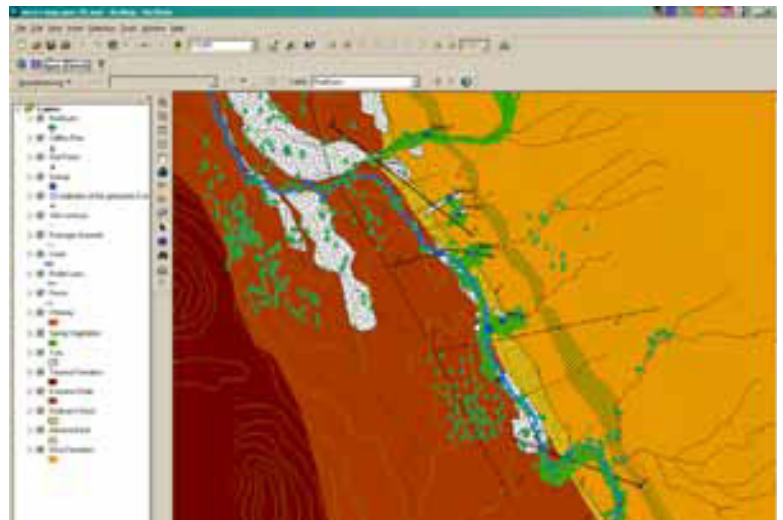
Click “Editor,” then “Save Edits,” then “Stop Editing.” The feature now appears as a layer (point, line or polygon, depending on what you have chosen). When all the features of the drawing have been turned into shape files, you can remove the scanned, rectified drawing and modify the color and texture of the displays to your taste.

In this way the map is built up and colored on the computer. It is somewhat analogous to the old method we used when the tacheometry drawings were traced onto the mapping film after they were all aligned to the Grid that had been painstakingly drawn onto the film.

Working on Your Map

Open up your map file and it will look something like this under the view. Notice all the ticked boxes on the left are shape files. Ticking them brings them onto your map, unticking them removes them from your map.

As a general rule you have polygons at the base of your legend and above them line files and at the top point files.



Preparing the Map for Printing

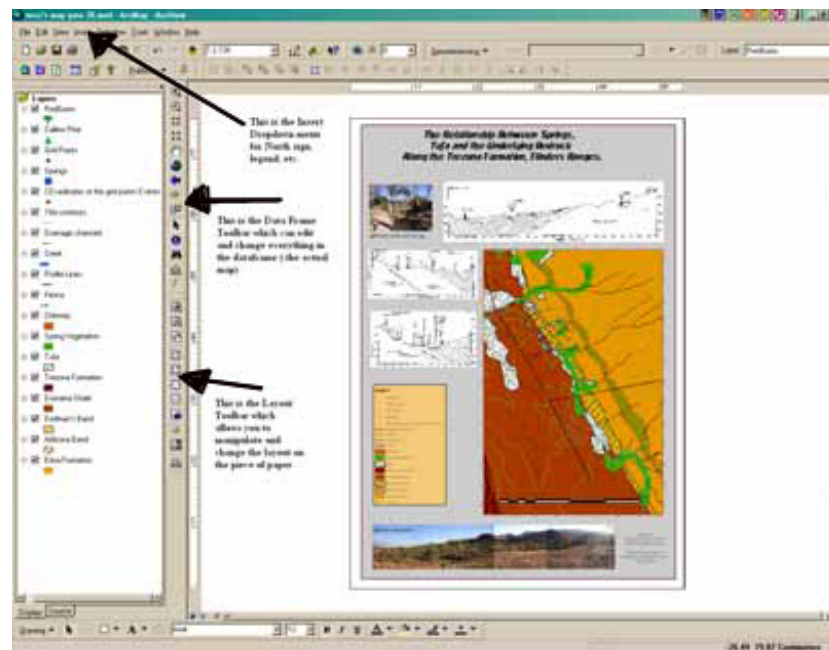
Arc Map has two connected screens or views, Data and Layout. Until now we have been drawing the map in the “Data View.” To layout the map as a finished product with scale, north sign, legend, etc., we go into “Layout View.” You can switch from one view to the other using the two buttons at the bottom of the screen.

The Globe is the data button and the Page is the layout button. The two arrows make the refresh button.



The layout button now places the drawing of the map onto a piece of paper whose size you can determine from the File Menu > Page Setup > etc. Here you can choose if the page you are laying out on is A4 or A1, Portrait or Landscape. From the View Menu go to Data Frame Properties and there is a whole range of things that can be chosen. Important for us is to choose the units of the map, which for us were meters (chosen under the General tab).

From the Insert Menu (shown here to the left), all the main design elements of the map can be chosen: text, title, legend, scale, north sign, and pictures.



The above screen picture shows the map in layout view with nearly all the features added except for the north sign. The black arrows show the location of the Insert Menu, the Data frame toolbar and the Layout toolbar.

When we started this project we were using ArcView 3.2 which is a smaller program than Arc Map 9 but is not as smooth to use. Arc Map 9 is really straightforward to add the above to, and in 2005 the students really went to town designing their maps individually.

Profiles

The profiles, which were created by the students using a combination of leveling and tacheometry and then drawn up by hand with the resulting number data, were scanned in to the computer as jpeg files and then inserted onto the page. There are tools in the software to adjust their size and location on the chart.

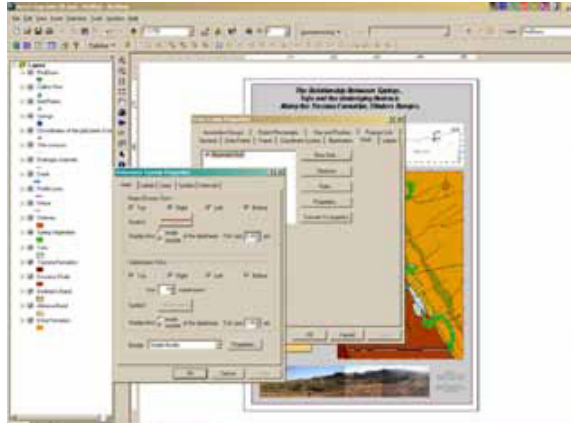
Grid

From the View menu > Data Frame Properties, you choose the Grid Tab and then

- Create a measured Grid
- Grid interval, 500m or 100m (whatever is appropriate)
- Tic marks
- Line width 0.1
- Choose color

All else default.

The dropdown menus for the Grid making around the data frame looks like this.



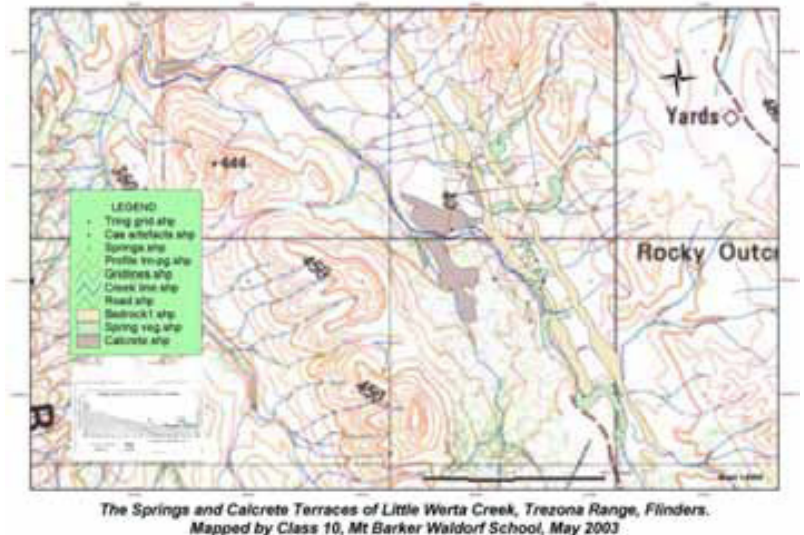
Export the Map as an Image

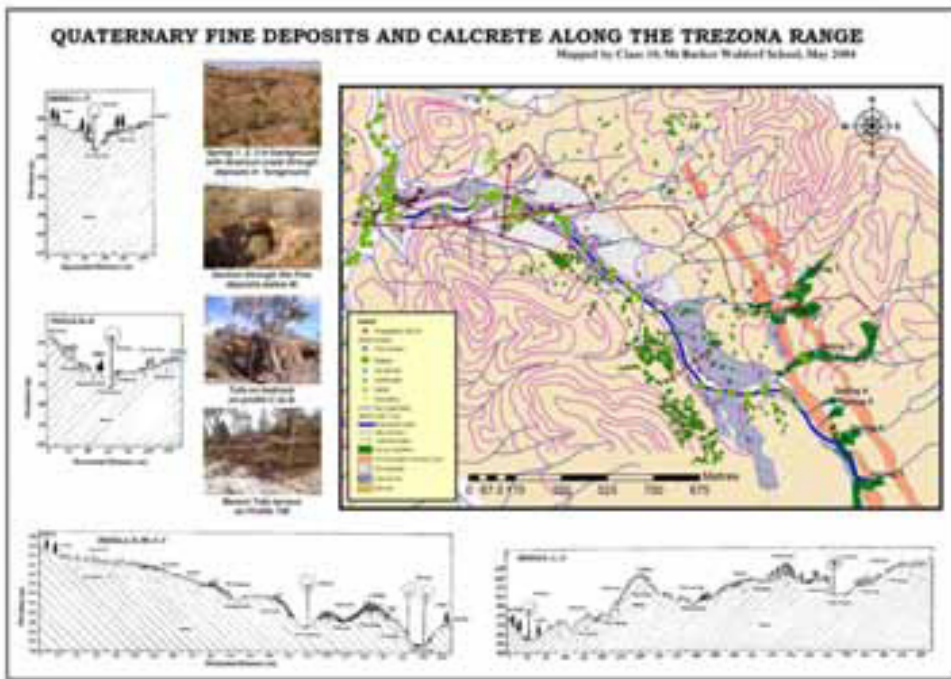
Once the chart has been completed to the satisfaction of the student or when the time has run out, the chart needs to be exported as a pdf file for printing. We had access to the use of a colored A1 plotter at a reasonable cost and were able to print maps there in 2004–2005. In 2003 we printed the maps as A4 or A3 sheets at school.

To export the maps go to the File menu > Export and then choose the file type (pdf), location and also resolution (300dpi).

Examples of the maps from 2003–2005

2003 Map with student data over a topographic map and one profile





2004 Map
One of two designs

Though the site was in the same area for the three years and there were overlaps, the actual mapping task differed each year. The depth of our knowledge of the site and its underlying geology has grown immensely. For 2006 we will move on to a new mapping task.



2005 Map
One of some 12 designs

Conclusions

In having done the surveying in this way now over three years, we feel that we have made a worthwhile step in modernizing the surveying curriculum, without losing the valuable educational steps involved in the traditional surveying techniques.

We reviewed the first year's work, which did have some problems, following the 2003 camp. Apart from the obvious problems with our own initial ineptitude with the new technology and the lack of efficient equipment (much of the initial equipment had been borrowed, or gifted), the main problem identified was that the students had too little relationship with the features on the map. This was because we had given in to the temptation of including on the map too many features which were simply add ons, but which the students had not produced themselves. The computer technology lends itself to making tasks that are difficult by hand easy to do. So, for example, we had included a background layer of one of the 1: 50,000 topographic maps of the Flinders. We realized in hindsight that the students could have easily felt that their own work on the map was relatively irrelevant compared to the work of the topographic map.

As a result we resolved in the second year, 2004, that we would confine the map, as much as possible, to the student's own work. This, we managed to do for the most part, except for the contours which were extracted as a shape file from the topographic map. It made a great difference, together with the greater proficiency we had developed with the techniques.

The process of scanning the tacheometry sheets into the computer, registering them to 'fit' onto the map with real coordinates, and extracting shape files from them, to which were assigned color and legend characteristics, was a satisfying one.

After the 2005 camp, we resolved that we would not take the computers with us on the camp but make sure that in the term prior to the camp the students would become familiar with the software so that we would not have to introduce them to that in the difficult confined conditions of the camp with 30 people sharing 15 computers in a tangle of power cords. That is now done much more efficiently back at school in half-class groups, leaving the time in the field freer during the evenings for the more pressing learning of surveying techniques. It is important in the field that the students do the drawings of both the tacheometry work and the profiles. This requires time, which would be easily squandered if we had the computers in camp.

The whole involvement of the students with the process was greatly enhanced and a couple of side advantages emerged in the relationship of the students to the computers. One of the negative aspects of students and computers is that the machines can become a source of entertainment (the games syndrome) rather than a tool to accomplish a task in an efficient and creative way. Students can sit in front of them for hours bringing up endless new images, sounds and animations. This is troubling both for the physical well-being of young people and also for their mental and social abilities.

In the setting designed above, the students are involved physically from morning to evening outdoors in sometimes-strenuous conditions, both physically and mentally. The results of these efforts are then summarized, computed and condensed into images and finally the map. The whole process is task- and skill-oriented with a balance of physical exertion, mental and manual skill accompanied by the intrinsic social work of being part of both a smaller working group and a larger working group where specialization is called for and the whole project is dependent on the unique, different skills offered by each member.

Table 1: Comparison summary of skills learned in traditional surveying with those incorporating modern technology.

Traditional Surveying	Surveying Combining Traditional and Modern Mapping Techniques
Setting out the triangulation grid	Setting out the triangulation grid
Learning the accurate use of an optical theodolite to measure horizontal and vertical angles	Learning the accurate use of an optical theodolite to measure horizontal and vertical angles
Learning how to use the theodolite to make accurate drawings of features of the map. Tacheometry	Learning how to use the theodolite to make accurate drawings of features of the map. Tacheometry
Learning to read a stadia rod	Learning to read a stadia rod
Use of a surveyor's band and Dumpy Level to measure the Base Line	Use of a surveyor's band and Dumpy Level to measure the Base Line
Learning to combine tacheometry and leveling to create an accurate profile	Learning to combine tacheometry and leveling to create an accurate profile
Using the sun to find true north	Using the sun to find true north
Applying the Sine rule to calculate side lengths of the triangulation grid	Applying the Sine rule to calculate side lengths of the triangulation grid
Graphic or coordinate plot of the grid	Coordinate plot of the grid
Design and drawing of the map by pen on tracing film	
	Use of GPS receivers to record geographical coordinates and elevation
	Use of Excel to create averages of geographical data so as to create data base files for the map
	Use of Arc Map 9 mapping software to georeference tacheometry drawings
	Use of Arc Map 9 to edit and create shape files for the map and then design the finished map

The project has been successful in both modernizing the surveying and in integrating computing in a balanced and holistic way into the wider education of the students.

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Index of Past Issues

Waldorf Science Newsletter: edited by David Mitchell & Bob Amis

This newsletter is published once 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
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Volume 1, #1

Partial contents – Acoustics in Grade 6; Teaching about Alcohol in Grade 8 Chemistry; The Chemistry Curriculum: The Debate over Teacher Demonstration vs. Student Experimentation; Spiritual Aspects of 20th Century Science; Overview of the Waldorf Science Curriculum; Water; Characteristics of the Major Sugars; Goethe's Meditation on Granite; Book Reviews; Humor; Poetry; Conferences; and Sample Experiments

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Volume 3, #5

Partial contents – Book Reviews; First Lessons in Astronomy; Steps in the Development of Thinking (Power of Judgment); Computer Science and Computers in the Waldorf School; Technology; Computers in Education; Some Characteristics of the Computer; Computers and Consciousness; Experiments

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Partial contents – A Chemistry of Process; Sponges and Sinks and Rags; How to Read Science; Experiences and Suggestions for Chemistry Teaching; Experimentation as an Art; Biographies—Dmitri Mendeleev, Joseph Priestley, Marie Curie; Destructive Distillation; Experiments

Volume 6, #12

Partial contents – Light and Darkness in 6th Grade Physics; The Relation of “Optical Elevation” to Binocular Vision; Description of Curves in Connection with Elevation Phenomena; Water Treatment at the Toronto Waldorf School; A Lime Kiln that Can Be Assembled and Disassembled; Experiments

Volume 7, #13

Partial contents – Thoughts on Returning to an “Education Towards Freedom”; Pedagogical Motives for the Third 7 Year Period; Social Education through Mathematics Lessons; A Vision for Waldorf Education; Our Approach to Math Doesn’t Add Up; International Mathematics Curriculum

Volume 7, #14

Partial contents – Conferences; Physiology, Update on Taste; Pictorial Earthquake; Boiling with Snow; Towards a Waldorf High School Science Curriculum for the 21st Century; The Thermal Decomposition of Calcium Carbonate; Crystal Reveals Unexpected Beginnings; Cosmic Ray Studies on Skis; Experiments

Volume 8, #15

Partial contents – Book Reviews; Arabic Science; Arabic Mathematics: Forgotten Brilliance; Making Natural Dyes; Exploring the Qualities of Iron; Von Mackensen Chemistry Conference; Oxalic and Formic Acid; Hydraulic Rams; What the Water Spider Taught Me

Volume 8, #16

Partial contents – Waldorf High School Research Papers; Inside the Gulf of Maine; How Do Atomistic Models Act on the Understanding of Nature in the Young Person?; The House of Arithmetic; Origami Mathematics; Sixth Grade Acoustics; Sixth Grade Kaleidoscopes; Tricks with Mirrors; The Flour Mill and the Industrial Revolution; Web Gems; Understanding Parabolic Reflectors; The Capacitor; Oscillation and Waves; Crystal Radio; Qualifications for High School Mathematics Teaching

Volume 9, #17

Partial contents – Book Reviews; Acknowledgement from a Waldorf Parent; Raising Money for Science; the Twelve Year-old Child and Orpheus; Towards a Sensible Kind of Chemistry, Part One; The Lightning Bug; The Ladybug; Exploratory Experimentation: Goethe, Land, and Faraday; Faraday’s Synthetic Investigation of Solenoids; Faraday’s Analytic Investigation of Induction; Geometric Addition Table: A Curious Configuration

Volume 9, #18

Partial contents – Book Reviews; Towards a Sensible Kind of Chemistry, Part Two; The Evolution of the Fast Brain; Professors Vie with Web for Class Attention; The Teenage Edge; Oscillator Coil Demonstration Using an Ultra-Low Frequency LC- “Tank” Circuit; Thermodynamic Experiments for the Middle School

Volume 10, #19

Partial contents – Book Reviews; The Beaver; Nature in the Human Being; Astronomy Verses for the Middle School; Child Development and the Teaching of Science; Bibliography for Middle School Teachers; What is Phenomenology?; The Design of Human and Animal Bodies; The Brain and Finger Dexterity; Observations of a Neurophysiologist

Volume 10, #20

Partial contents – Book Reviews; A Number Story for the Sixth Grade; Novel Entries for a Trig Table; An Introduction to the Sine and Tangent; Toss Out the Toss-Up: Bias in Heads or Tails; Phlogistron Theory; Song of the Rain; Refrigeration in Physics; The Poetry of Astronomy; Build Your Own Sextant; Highlights from Recent Science-teaching Periodicals; Websites of Interest

Volume 11, #21

Partial contents – Books of Interest; A Sampling of Poems for Botany; How Does Sense-Nerve System Activity Relate to Conscious Experience?; Acoustics in Sixth Grade; Fun Facts of Physiology; About Formative Forces in Vertebrates and Human Beings; Global Perspective; Points to Consider in Science Teaching; Deconstructing Black Box Aspects of a Computerized Physics Lab

Volume 12, #22

Partial contents – Books of Interest; Preserving a Snowflake; Environment, Morphology, and Physical Principles for Waldorf High School Teachers and Students; Homemade Audio Speaker for Grade Eight; Mathematics and Natural Science: A Reflection from the Viewpoint of Pedagogy and the History of Ideas; Animal Sight; Kepler’s Model of the Universe; Teaching Sensible Science; Mug on a Glass: An Optics Demonstration for Grade Seven; Chemistry Challenge for Grade Eight; On Being an Insect; Surveying and Mapping: An Attempt to Integrate New and Emerging Technologies into the Class 10 Curriculum