Education in America: science for survival

Part 1, by James W. Frazer, Ph.D.

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This is the second article in a series on educational curriculum reform. The first, "Restore Classical Education to the Secondary Classroom," by Lyndon H. LaRouche, Jr., was published in two parts, on Aug. 29 and Sept. 4.

The editors find Dr. Frazer's proposals for curriculum reform in science and technology to be very exciting and thought-provoking. While we do not agree with all of his suggestions regarding music, history, and literature, we are publishing the article in full, in the interests of sparking debate. Further contributions and responses are welcome.

Recently one of my grandsons told me his rank order of reasons for attending public high school:

1) Meet girls.
2) Get on the football team.
3) Be popular with other students.

My grandson simply didn't believe that anything taught in school would have any real value for him. He has little or no respect for those charged with teaching him in class.

That grandson now has some part-time jobs—in his father's shop, sometimes as a plumber's helper, a little as a dancer. He argues that no employer really cares about high school diplomas or grades if a worker has a creditable work history.

I was chagrined at such thoughts within my own family, but the opinions my grandson expressed are quite prevalent among putative students of high school age, many of whom are going to drop out.

As a consultant for a well-known concern, I helped prepare some "achievement" tests for a populous state. I became quite vexed by the vocabulary allowed in tests for that state—about 1,600 words. The limit was set by the educational agencies of that state. I dug up some of my father's eighth-grade texts, circa 1918, and found that these texts would not be allowed in present-day schools during the twelfth year because they required a vocabulary of some 3,000 words. My father had memorized some of the prose and poetry from those texts and could still recite them some 60 years later.

A rather smug crew of ex-teachers pointed out the "elitist" population of schools in those times. This crew of "experts" did not think such training appropriate for present-day schools. Horatio Alger definitely cannot happen. Horatio Hornblower is about a forgotten human experience of no import. Alas, the idea of personal leadership is lost in a sea of peer-induced conformity.

During my own formative years, I was an academic student, but was also exposed to a lot of shop work, both at home and at school. I worked with lathes, drill presses, castings, electricity, and electronics in woodworking and automotive shops. Dewey's "learn by doing" as then applied meant that one received a lot of hands-on experience in addition to academic work. I'm not sure it was intentional, but this kind of instruction made the more abstruse algebras, trigonometry, and geometries easier to comprehend and manipulate, and instilled some confidence in my own insight.

Recent publication of *Science for All Americans* by Project 2061, sponsored by the Department of Education and the American Association for the Advancement of Science (AAAS),* has focused attention on the production of "informed" students. This publication assumes, up front, that

* *Project 2061: Science for All Americans,* AAAS publication 89-015, AAAS, 1333 H Street NW, Washington, D.C. 20005. The fundamental premise of Project 2061 is that schools do not need to teach more and more content, but should focus on "scientific literacy" and teach it more effectively.

In a class on electromagnetism, a student uses a lathe to build an experimental apparatus. "This kind of instruction made the more abstruse algebras, trigonometry, and geometries easier to comprehend and manipulate, and instilled some confidence in my own insight."

most Americans are not to be involved in "science." In general, decreased assimilation of "fact" is to be accompanied by increased attention to creativity and appreciation of the "methodologies" of scientific thought. One gets an impression of Omphaloskepsis winning out over gritty hands. This struck me as very odd, and I discussed it with one of the ex-school teachers. She asked me to write down the methodology of scientific thought so it could be tested! We scientists are given no credit for creativity, even by secondary school science teachers!

Recently, a son-in-law who once thought he had an agreement with higher education—they could go their way while he went his—decided to repair his car. He used some of the latest bonding materials, carefully placed aluminum, magnesium, and iron castings, pumped down and de-humidified the air conditioning system, used some very sophisticated composite hardening materials, repaired the radio and installed a high-output amplifier, replaced some faulty electronic components, and used some of the latest acrylic paints as a finishing touch.

This person, excluded from materials he thought valuable while in formal school, has used the products of many different kinds of research and educated himself quite well in the process. One wonders why school systems are so adamant in not providing this kind of education in the first place. The answer, of course, concerns cost and lack of teachers. But what is the cost of *not* giving this kind of education to millions of Americans?

The goals of education

The real concern of education, in all its forms, is the passage of accumulated human knowledge from one generation to the next. The schools are one of the predominant instruments we have chosen to assist in doing this. The objective of this education is to produce a socially knowledgeable, technically competent citizen equipped to adapt to a constantly changing world. The Three Rs are an absolute requirement, and most children would like to read about things they consider important. By the tenth year, some idea of a life pursuit goal, along with some practical means of attaining the desired goal, should have appeared.

Since 1950, forms of education other than socially approved curricula of public schools have appeared. TV has a larger audience than the schools. With the increase in the number of working parents has come a decrease in parental supervision of the young. To some extent, day care programs fill the gap in middle and upper income families, but, increasingly, the streets and peers have supplanted parental supervision in home education. With only a few exceptions, national TV qualifies only as a "street" education, and not a very good one at that, though the medium occupies some 2-6 hours a day of children's time during their most impressionable years. One result of this "de-familization" of American children is a total lack of respect for the little parental direction that remains. It is not uncommon for younger children to hear something from an adult, then check with their peers to see if that is really true. As another result of this continuing de-familization, the agencies of society, including the school systems, have had to take on jobs which were the jealously guarded domain of the parent in previous generations.

The broad question being answered negatively by U.S. society is whether a social democracy can long endure when its citizens know little of their government, don't participate in its local functioning, know nothing of the history of human mistakes, and have lost in diversity a sense of community. Lincoln's Gettysburg Address expressed concern about differing sets of goals. Lincoln could not have imagined the present chaotic state of non-participation and negativity. We have become, to an embarrassing extent, a nation of slack-jawed worshipers of electronic entertainment who place little value on a sequence like knowing, thinking, synthesizing, *doing*.

We are among a generation who believes nothing shown in electronic media really happens. There are groups that don't believe anyone has been in space or to the Moon, disapprove of learning too much about the solar system (let alone the universe or cosmos), strongly disapprove any mention of evolution, and adhere tenaciously to the 16th-century Bishop of Ireland's calculation showing that the world began in 4600 B.C. and was peopled days later. Old bones and fragments, they believe, are put there to confuse and entice us. These groups are so ill-informed that they don't realize an entirely new theory of nuclear physics would have to be developed to counter known data on isotope decays used to date most archeological investigations.

Since nothing that happens on TV is believed to really happen, it would seem a poor idea to use TV or computers as teaching media in the absence of other types of educational work. This is particularly true if computers are used in a preprogrammed mode with little presentation, or comprehension, of real events.

Real events are the ones a student can see, touch, hear, smell, taste, and relate to his own more limited experience, independent of the judgment of others. An adult who leads him to these events or discoveries gains credibility with each predictive success, but the time between prediction and success must be very short for young students (no more than 45 seconds in most cases).

With some sadness, we observe the following as desired competencies for secondary science listed by Project 2061, the National Academy of Science's august body of experts: 1) elementary shaping techniques; 2) some use of hand tools; 3) barely enough mathematics to make change at the local supermarket; 4) ability to read and record analogue or digital instrument outputs.

In what way does this list of four differ from the records left by cavemen?

Project 2061 recommends teaching a minimum of subjects so that time for a maximum comprehension can be had. Throughout their recommendations they disdain "knowledge" for attempts at developing reasoning ability, especially reasoning in groups. The Greeks before Pericles were long on reasoning ability. Imagine the present world if they had had more knowledge to reason with.

What then, is to be done?

I believe it a healthy step to recognize that problems in the schools are only a symptom, not a cause, of a social malady. The actual malaise is with the American people themselves. Schools have tried many different approaches to increasing public awareness and participation such as PTA, home room "mothers," booster clubs for bands, athletics, bumper stickers for the academically successful ("My child is an honor student at . . . school"), evaluations of progress, parent-teacher conferences, school fairs or carnivals, and many others. If success is measured by response to taxes at the ballot box, these measures may have had some motivational effect, but the major problem remains: How does one convince parents that the appropriate education of their children is the most important goal of their lives?

A hands-on approach

The following steps are necessary:

1) Operational, hands-on knowledge of the real world should begin to be acquired in early school years. Introduction to counting should be with an abacus in the first grade, or in pre-schools. Objects should be counted in a large number of settings. Pupils should measure play areas with tape, alidade, and spirit level.

2) Early grades should acquire experience with molding and shaping techniques. Molding and firing clays, balsa wood modeling for take-home models, model building with weights, and units measure emphasized during construction. After exercise material is complete, planning (line drawing with dimensions) and building a personal project should occur, using glues and fasteners. Both sexes should participate in these projects. Use of low-power electrical scroll saws and other tools for low-power shaping, molding, and polishing should be emphasized.

3) Musical ensembles with school-supplied bells and recorders should be formed in the first grade. Music teaching should continue through the sixth year, and by preference thereafter. Students should enjoy part singing by entry to the fourth year. Full-size statues of composers and authors, or figures of history, should be placed in primary education areas and changed periodically. These are to be constructed by students in their ninth to eleventh year (see below). Each statue should have a large plaque showing period, who, and where. Teachers should include discussions of the statues in their lesson plans. A piano and good stereo sound system should be part of normal classroom equipment. The statues of composers or authors should not be limited to western culture. Neither should the lesson plan.

4) Whether source material is in computers, work papers, or books, reading is a fundamental requirement for any civilization. It is the predominant method of passing the knowledge of one generation to the next. Reading becomes even more important in the absence of traditional home life, since it partly supplants education by elders now.

Reading will not be learned, however, unless it is both pleasurable and important. The directions for each classroom activity should be printed and passed to each student, beginning in the earliest days of the first year. The teacher then helps decipher them and arrange the work. As soon as ability allows, written reports should be required, certainly by the middle of the second year of school. These reports serve two major purposes: first, so that the pupil can synthesize and arrange his own ideas; and, second, as a conditioner for habitual speech patterns.

Obviously, a single teacher with a classroom of 30-40 very busy, squirming, talkative juveniles, mostly lacking any idea of self-discipline, is not going to do all of this alone. We suggest use of a double-edged educational tool, particularly in the primary years of school. For reasons explored more fully later, tenth-, eleventh-, and twelfth-grade students are to have "service time" during the school day. Some of these students are to be used as assistant primary instructors and are to be paid federal minimum wage. Ideally, there should be one assistant instructor for every three pupils. As discussed later, the tenth-year curriculum is to contain a course in child development and educational technique. The primary teacher must have time to discuss plans for the day and longer-term educational goals with these assistants. The primary teacher becomes both a mentor for the assistants and supervising instructor for the primary class. The primary teacher is required to have a background in child and adolescent psychology, as well as a strong subject background.

There is a uniquely American precedent for this practice. The first eight years of school were often taught by high school graduates, well into the 20th century in the United States, with considerable success. While no one wants to return to the country schoolhouse, use of selected secondary school students as primary year teaching assistants should be implemented.

Secondary school students would have to be selected for this experience, since students with undesirable social behavior would have to be excluded. Given the present extreme sensitivity to peer pressure, appointment as a teaching assistant may be regarded negatively by many students, especially in central city schools where help is most needed. Labeling the class as a "school service' class is very important, for other services can also use student help, to the benefit of the student. Cafeterias, maintenance shops, administrative offices all could dip into this pool of unused help. Transportation of students to and from their school service areas would have to be arranged.

The sum of this program aims at development of a more responsible person in upper school years, with less free time, productively employed early in life and more knowledgeable of human growth and development. The primary student receives a more intensively supervised learning experience.

Teachers, already overburdened with tasks dividing their teaching attention, would find themselves executives managing an enterprise with five or six middle managers (students) and planning classroom activities to be carried out by those students. Both the classroom teacher and the assistant instructors would require preparation time away from the classroom.

5) This type of hands-on instruction requires investment in non-traditional classroom equipment, indeed, a revamping of classroom design. Materials such as balsa wood, plaster, forms, thermoplastics, low-power bench lathes, scroll saws, buffers, polishers, transit, alidade, measurement chains, bells, sound system, recorders, and pianos. All this in classrooms for years one through four.

An upper-year project (years 11-12) would be construction of a Buckminster Fuller triangle and pentagon approximation of the Earth's surface, where individual segments could be removed for study on a flat table, then restored to the globe. The model must be to scale, with surface features amplified. Latitude and longitude are to be annotated on each segment. These should be used in years one through eight, so that each primary classroom should have one. Navigational and weather system movements should both be worked on such a surface.

6) In the third year, simple electrical circuits with aluminum foil conductors, three-volt (Christmas) lights, conductor switches, and a variety of board patterns should be constructed and used. Students should graduate to the use of three-volt neon bulbs and circuit boards, and finally, by the end of the fifth year, they should be using design boards and simple integrated circuits.

The previous experience with an abacus should transfer to Nandnor and other types of gates for simple ladder networks. Some students may already have Nintendo games or other computer games at home. A Chinese second grader, with whom I am acquainted, regularly does his homework on his dad's computer at home, and has become quite proficient. Such families indicate the possibilities of training at an early age, but also pose a social problem, because less fortunate children with equal innate ability won't be able to keep up. Their disadvantage increases with time, since they have less input from their parents. In other circumstances, with less intelligent but solvent parents, a child may run several game programs on a computer with no appreciation of programming or mathematical or constructive uses. Since he regards the computer as a preformed toy, he has neither motivation nor background for further development. Such students are guaranteed to disrupt classes in circuits or serious computer architecture. Part of the reason for starting studies of simple arithmetic with an abacus, is as a social leveling device: Parents can afford one in the home. The ones furnished in school are made by sixth-year students as a service construction project.

Summary: first through fifth year

The hands-on approach is implemented by student assistants under the direction of a professional instructor. This applies to reading, writing, elementary arithmetic, measurement, electronics, and computer operation.

The following goals should be possible:

1) Read and write at average eighth-grade levels currently considered acceptable.

2) Have arithmetic ability equivalent to the current sixth-grade level, but also experience with the Pythagorean theorem, and notions of geometry as applied to surveying, navigation, and construction. Note the implementation of circular action in celestial navigation.

3) Have basic notions of direct current (d.c.) electronics well developed, including Ohm's law, circuit symbols, and ability to construct simple battery capacitor flash circuits and ladder networks from memory.

4) Have read, been read to, and fantasized in writing about the Rumpelstiltskin stories, Count Von Luckner, Grimms' fairy tales, and Melville's *Moby Dick* (with emphasis on Melville's personal experience, similarity to passion plays, the geopolitics of whale oil, the geographies of passage, and the social essences of leadership). Melville's epic can also be used as an introduction to mechanics by describing the sail and rudder positions of a sailing ship, hands-on experience with a fan, sheet, 2″×6′ dowel, four spring scales for measuring the vector direction of transferred force, clothesline, and eight small pulleys. This could be a major class participation project with data reduction and analysis by graphs as an output. Some of the class will have family sailboats, but very few will have made this extensive an analysis.

5) Guided written reports are required of all hands-on activities. Class notebooks are kept by each student and are reviewed by the teaching assistants daily. These notebooks are worthy of considerable attention by students, instructors, and parents.

6) To those who object to hands-on instruction, we comment that ages 6-11 are the ages of model construction, race cars, electric trains, with a maximum of fantasy and little parental direction. Sadly, commercial models have become snap-together plastic and do not represent the "drawing to reality" objective which we desire. The objective is to use fantasy to produce a plan, scale drawing, and finally a constructed object. The theme "drawing to reality" should be repeated as often, and in as many contexts as possible. The pupil should be encouraged to reduce his ideas to dimensional drawing, then to a final construction to scale. This is one area where the use of computer graphics would be a great asset.

7) Beginning in the first year, an intensive sequence of biological sciences should be taught—again, with a hands-on approach. Seeds are planted and growth is measured, with a ruler and later gravimetrically—the whole plant, and the same plant dried. Water content can be measured. Later, simple analyses for protein (xanthoproteic reaction), cellulose (cellulase digestion followed by the orcinol reaction), fat (extraction with chloroform), and ions (flame photometry) can be made. It will probably be the fifth year before all of these techniques can be utilized. Trees should be planted, growth and circumference measurements made annually at least, and the tree should be carefully examined during different seasons of the year for types of insect, mold, and other types of plant diseases, including viruses.

Trees such as peach, plum, and apple should be utilized, so that a school orchard is gradually formed. Fruit collection could begin during the fifth to eighth year if the tree is planted during the first school year. This sequence could be difficult for inner city schools unless property is acquired for a park-orchard near school property. An alternative would be bi-monthly busing to property acquired outside the city. The latter is preferable, since these outings could also be used for insect trapping, plant collecting, and other environmental examinations. Winter visits could be used for wildlife tabulations, examination of geologic formations as appropriate, and careful examination of the evening and morning sky, as an introduction to astronomy and navigation. Use of cameras could produce star-streak photographs at different periods of the year. Such activities imply year-round schools. There is little reason, in urban environments, for the present agriculturally derived school cycle. There is also little reason, in a highly mobile society, why schools always have to be located in one place with one set of facilities.

Almost immediately there would be parental objection to school-supervised overnight outings. There would also be criticism due to financing: supervisors, property, building upkeep, buses, drivers, etc. Parkland may be objected to because of tax loss, socially unacceptable behavior, cost of policing, etc. Rebuttal is not easy, but would include reference to the cost of prisons, cost due to theft and larceny, costs due to social neglect of all kinds.

If parkland were utilized, growth and development of small farm animals might be undertaken, with egg production or some meat production a side benefit. There would be a reaction from animal rights activists, but the educational benefit of measuring growth response to variations of diet and environment would be considerable. From this activity, an introduction to nutrition, data collection and treatment, computer use to reduction of long-term data, construction of graphic presentations, and verbalization of observations during hands-on growth experiments could accrue. The demand on the primary teacher would be great, and the use of assistant instructors to oversee such projects would be absolutely mandatory.

The proper care and maintenance of small animals and orchards would also require development of some knowledge of microbiology. Specimens obtained from the plants and animals could be subcultured and tested on growth media. Quantitation of numbers in fecal material and the dissemination of the fecal material to the surrounding areas could be measured. Such collections should be possible beginning in the second year and gradually becoming more complex. It is imperative that students become much more aware of the microbial populations around them, and the basics of public health maintenance, at a very early age. Some of the specimens will contain small protozoans, crustacians, rotifera, and insect pupae. These can all be added to the students "studies of life" armamentarium.

One objective of this introduction to microflora and fauna is simply to convince students and their parents that the micro world is there, ubiquitous, an all-permeating feature of every environment.

Such findings can lead quite naturally to discussions of human disease and its causes: tuberculosis and histoplasmosis, strep infections (ears, throat, bronchi), scarlet fever, measles, mumps, chicken pox, shingles, salmonella diarrhea, venereal disease, and diphtheria.

Such discussions and demonstrations should all include the beneficial uses of microflora. Cottage cheese should be made in class—made by the natural way and also by the acid method. The ecological importance of wood rot, the relationship of intestinal flagellates and termites, and vitamin elaboration by intestinal microbials are just a few uses which may be shown.

Effects on the school day

Present school hours were arranged around the agricultural day. There is no longer a reason for those strictures. The school day should be lengthened to 10 hours, including rest and quiet times. Such a maneuver would require a one-third increase in teaching staff, and more teaching assistants. As can be seen, this program could not work without a supply of one teaching assistant for every two pupils in years one through three, and one teaching assistant for every four pupils in years four and five. Eleventh- and twelfth-year students would have long days, and would not usually be employed outside the school. The loss of income is made up by their pay from the school system for their service activities.

Such an arrangement may seem draconian to some, but many band, orchestra, and athletic team members already have 10-plus-hour days. Is that draconian? Such a program might seem expensive, but some of the costs are recouped by a decrease in adult employment, with the added benefit that there would be an annual turnover in lower echelon "blind alley" jobs.

Fifth through ninth years of school

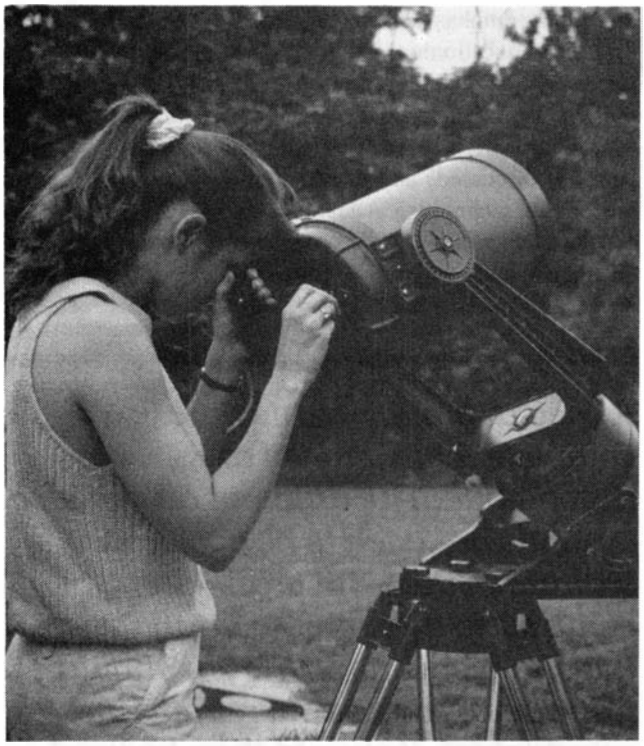
Reading, reading comprehension, languages, and communication are heavily stressed in this period, building on the reading emphasis of earlier years. It is the students' greatest time of questioning, imagination and emerging multiple skills. Stories of Jules Verne, NASA's history of rocketry, biographies of Henry Ford, the Wright brothers, Goddard, Martin Luther King, Goya, Rubens, Einstein, etc. should all be read, discussed, and placed in a setting of their times. Histories of technological development are reviewed: electrical nets, electronics, steel, coal, transportation, industrial chemicals, and many more. These histories of development are accompanied by hands-on projects such as construction of a model steam engine that runs, construction of an electrical distribution net with computer load control, formation of plastic molds, examination of the molecular structure of insecticides, and their effect on bacterial mutation rates or on the mutation rates of fruit flies.

A special project at this time is a complete tear-down of an automobile. The different automotive systems are each to be explored starting in the sixth grade and continuing through the ninth year. At the end of this time, the car should have been completely rebuilt and refurbished. It should then be used for a class picnic at the class orchard. The car is then sold to finance other class activities.

These readings are used both for comprehension and as part of the history of technology. In addition, they are coordinated with the hands-on approach to teaching physical science. The construction projects all are accompanied by the teaching of such units as alternating current (a.c.) electricity, the gas laws, the Carnot cycle and thermodynamics, and the principles of internal combustion engines (gas and diesel).

A special project starting at this time is a complete teardown of an automobile, preferably an American-made model. The different automotive systems are each to be explored starting in the sixth grade and continuing through the ninth year. At the end of this time, the car should have been completely rebuilt and refurbished. It should then be used for a class picnic at the class orchard. The car is then sold to finance other class activities. The funds are controlled by the class itself.

In addition to the readings used to teach physical science, other readings are utilized to show the beauty of the spoken



Use of a telescope at the Von Braun Observatory in Huntsville, Alabama. Visits outside the urban area can provide an introduction to astronomy and navigation.

language, each set of readings accompanied by oral presentation and written critiques and comparisons. There should be a thorough classical as well as modern introduction: Shakespeare, Goethe, Thoreau, Hawthorne, Whittier, and Riley should be included, in addition to Lewis, Cummins, and other more modern writers. Introduction to other languages such as Latin, French, German, Spanish, Russian, Arabic, Chinese, Hebrew, Zulu should also be accomplished. This introduction should be accompanied with descriptions of the history of the language groups, their geographical distribution, time zones, relationship of times and the motions of the Earth and planets that make time considerations important.

During this time also, there should be an introduction to the history of philosophy. The title philosophy is used loosely. One would prefer some word for the history of what peoples have thought about, what they did about their thoughts, and, with imperfect, perhaps slanted hindsight, how successful were their conclusions and actions. A special set of readings is appropriate in this connection, which should include Louis Lamour's *Walking Drum*, Kant's *Fundamental Principles of the Metaphysics of Morals* and *Letters on the Aesthetic Education of Man*, Plato's *Republic*, and Plutarch's *Lives*. These readings should be accompanied by investigations of archeological findings representing the different periods of human development. An adroit teacher is required, because a considerable amount of attention should also be given to isotopic dating techniques, their accuracy and limitations. A heavy emphasis should be brought on the fact that alternative notions of dating require an entirely new hypothesis of nuclear physics which is compatible with known observational data now in hand. Contention should be expected and prepared for. The Olduvai Gorge, Java, and Sinkiang findings; the Egyptian dynasties and the flowering of Greek culture, with its spread under Alexander, should all be compared to the rise of civilizations in China.

During the discussions of each of these periods, the nature of the evidence should be carefully explored. The inscriptions, monuments, and what survives of early writing bespeak a leisured class of humans and the views expressed may not be those of the common people living at the time.

Euro-American cultures are composed of egotists. Every child knows that Columbus discovered America, but, if so, why did he have problems with the Carib Indians who were already there, and still are? The Americas were already populated at that time. Some of their inventions are still with us, e.g., the spigot on your bathtub (Aztec), penicillin (Aztec, lost 300 years, then rediscovered), potatoes (Inca), maize (Central America).

Rather than a European-outward view, as is usually presented, it is hoped that a more detached view of the interaction of differing cultures can be presented. There is no doubt that European achievements in arts, mathematics, and the philosophies (including natural philosophies) have become a dominant feature and way of life desired by most of the world's populations. But each with a different cultural background. The "rubbing" of one culture against another has often been punctuated by warfare, but also gives an appreciation. What kind of a society did the Mayans have? Which societies believed in perpetrating themselves by educating the young? Was everyone in the society given access to education and other keys of power, or was there an elite group which controlled access to more easily control the others?

While in some parts of the United States, it is illegal to include religion in scholastic studies, the philosophies espoused by differing religions should be studied. Thus, readings from the Koran, the Rubiyat, Buddha, and the Bible could be selected from this point of view. Understanding the different philosophies is important economically as well as educationally, since the present hemorrhage of American wealth in exchange for oil and manufactured products of limited time utility will ultimately lead to ownership of much of American industry by populations espousing those beliefs, if we continue on our present course.

Sixth through tenth years (an intentional overlap)

Early experience with numbers, the abacus, computers, and d.c. electricity should have prepared the student for further mathematics. This is begun using Keplerian and Eulerian geometries of both plane and space-filling geometries, including line figures, polygons, and Kepler's Golden Section.

All of these are logical extensions of previous shop practices with solid objects, and are extended in this period in constructing artistically pleasing objects, furniture models, and models of the complex polyhedra. Transparent polyhedra with their constructed normals introduce plastic casting and the chemistry of catalytic crosslinking, as well as the forming of plastics by more conventional tools, thermoplasts and routing, and cutting and grinding to specified dimensions.

The trigonometric identities learned during this process are used to approach an algebra of space. The expressions of ellipsoids of revolution (actually constructed on a journal lathe), and conics (constructed on a lathe, then sectioned to produce paraboloids, hyperboloids, and the geometries of the solids represented by the section). Since small increments of position are used in all of these forming techniques, exactly calculated beforehand, modeled on a computer, and then constructed, the step to a calculus should seem quite logical to the student.

Shop practice required for these activities includes metal welding, joining, and molding of various plastics, use of cutting presses, bar folders, collet and journal lathes, inside and outside milling machines, sputter polishing and testing of solid properties such as hardness, ductility, chemical resistance, and chemical properties of materials. Teardown and reconstruction of the auto continues.

During this time an educational payback begins. Some of the shop products will be those already listed as required in the earlier educational years. The abacus, the Buckminister Fuller globes, and many other materials are student constructed with supervision from more advanced students. Such a function could be called exploitation of the student in some areas of the country, so that contention should be expected and prepared for. It is also true that there would be a decrease in school procurement of these objects as a result of the student work, but it is also true that present teachers are not sufficient to fulfill the demand this would create, so that there would be an increase in the market demand for those able to teach shop practices in conjunction with an academic approach.

The main goal of this effort is not the payback, though that is important. The main goal is to develop in the student a sense of required timing and the meaning of commitment to a goal. The major theme of passing the wisdom of previous generations to the present generation should be continually emphasized. To that end, the student's first introductions to forming machines should be the treadle-operated machines of the 18th century. Several of these should be displayed in the shop area. One of the construction projects should be a functioning water wheel with a water turbine. Another should be a functioning dynamo which can be used in the formation of the fifth year electrical nets. From these, the student should form a hands-on idea of the history of technology and the ways in which technology has developed.

Electronics (including elementary electromagnetics)

The student has already had experience with d. c. and a. c. circuits, simple gates, and Boolean algebra of computers. In this age range, audio electronics are of great interest to most students, to include power supplies, audio amplifiers, speakers, and speaker enclosures. Each student should construct all of these, allowing an introduction to the theory of operation of solid state devices, power dissipation mechanisms, and the chemical basis of these devices.

Part of the study of basic properties would utilize polarograms, electrochemical plating techniques, quantitation of electrochemical gas production, and simple amperometric titrations to arrive at the meaning of dissociation potentials and the electronic structure of matter. The student should arrive at an appreciation of the electronic structure of matter on the basis of much previous practical experience. From this point, he can progress to fuel storage cells, photovoltaic cells, phototubes, and get an introduction to the study of optics with standard light sources, replica grating interferometers constructed in shop, and simple lens systems with experimental results quantitated by means of the phototubes.

The Sun's spectrum should be measured quantitatively, with the Frauenhofer lines, and both emission and absorption spectra should be quantitatively observed. The correlation between electron emission and the energy of photons should be well established by the end of this construction.

Studies of bioenergetics using self-constructed instruments

The constructed photometers can then be used to study the emission and absorption spectra of dark-adapted and light-adapted plant leaves, as compared to other parts of the plant. From quantitative difference spectra, the student should be able to distinguish a mixture of chlorophyll and cytochrome spectra, then proceed to spectra obtained from purified compounds isolated from those sources. Similar spectra can be obtained with *Neurospora mycellia* exposed to different oxygen concentrations. Reference should be made to the E_0 values of the cytochromes, and the energy available from this source calculated. A similar experiment can be performed with the earthworm *Lumbricus*. Although experiments with higher animals may be objected to, use of a simple ear oximeter (to be constructed in shop), sensing hemoglobin oxygen saturation, should allow students to do breathing experiments themselves. Exercise could also be tested. Such experiments should be followed and coordinated with heat-balance studies using oxygen calorimetry on themselves at complete rest, standing, and while pumping a quantitative bicycle ergometer.