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ABSTRACT

This newsletter for the Engineering Concepts Curriculum Project includes the educational objectives in the affective domain for the course. The major categories for these sixteen objectives are: (1) Interaction of science, technology and society; (2) Matching technology to people, society and the environment; and (3) Use of technological concepts. The activity approach, content, and format of the materials are described. The teacher's instructional materials, including a manual, are briefly summarized. Also included is a technical note entitled "Man and His Numbers" which traces the historical development of several numeral systems from primitive counting to Binary Coded Decimal notation. (Author/TS)

The Man Made World

ECCP Newsletter

ENGINEERING CONCEPTS CURRICULUM PROJECT

VOLUME IV, NO. 6 FALL, 1971

TMMW OBJECTIVES IN THE AFFECTIVE DOMAIN

THE MAN MADE WORLD course is designed to develop technological literacy among all students in this age of technology. Put differently, future citizens, in order to control the growth and use of technology need to develop some understanding of the characteristics, capabilities, and limitations of modern technology. Technological literacy involves the development of attitudes towards the use of technology for individuals and society, as well as the learning of cognitive ideas (concepts, techniques, skills, etc.). There are approximately 100 cognitive behavioral objectives stated in the teacher's manual. The following statements however, describe the major course objectives of TMMW in the *affective* domain. After taking TMMW course, a technologically literate student should be able to:

(1) Recognize that technology will create entirely new possibilities for people and society. As a result, the world will be a different place to live in the future, and that only knowledge of both technology and society can insure that it will be a better place in which to live.

(2) Recognize that we live in an age of rapid technological change and our ability to adapt to and control modern technology depends on our understanding of its characteristics, capabilities, and limitations.

(3) Develop the awareness that society, its culture and values are constantly being influenced by advances in science and technology, and that culture and the values of society should affect the direction of changes in science and technology.

(4) Understand that modern technology is related to both "pure" sciences and social sciences, and that solution of societal-technological problems requires a multi-disciplinary approach.

(5) Recognize that when using the products of technology, it is important to match machines to people and technological systems to society.

(6) Weigh the benefits and possible side effects of technological "improvements" on the environment.

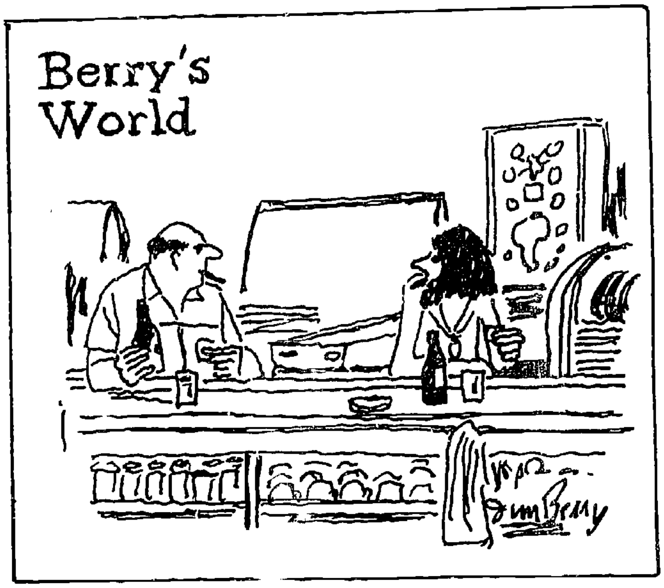
(7) Consider the need for governmental support of research related to the matching of technology to individuals, society and the environment.

(8) Consider the idea that survival of the human race requires that we look upon the earth as a closed system (i.e. space ship) in which resources must eventually be re-cycled.

(9) Attempt systematic (rational) approaches to decision-making and avoid emotional reactions to complex problems.

(10) Recognize the need to look for multiple answers to complex problems particularly in the area of science-technology-society interaction.

Realize that decision-making in a complex world usually involves trade-offs among alternative courses of action.



"Let's drink to coming out with simplistic slogan solutions to complex issues."

(12) Investigate the possibility of utilizing the tools and techniques of technology for analyzing and solving problems outside the area of technology.

(13) Recognize that machines including computers have limitations as well as capabilities.

(14) Recognize that the development of criteria and the stating of constraints in a decision problem are usually subjective activities.

(15) Recognize that when analyzing complex systems it might be just as illogical to attempt to use too much information as it is to use too little.

(16) Realize that many complex machines, such as digital computers, are made up of systems composed of simple understandable parts.

The objectives stated above can be divided in three major categories as follows:

(a) Interaction of science, technology and society (1-4).
(b) Matching technology to people, society and the environment (5-8).
(c) Use of technological concepts (i.e. system analysis) and tools (i.e. digital computer for analyzing and making decisions about complex problems (9-16).

An experimental attitude survey (30 items) has been devised to attempt a measurement of changes in the above mentio[illegible]. This survey was used with participants at ECCP [illegible] for high school teachers this past summer. An an[illegible] the results is currently being done and a report of [illegible] will be reported in the next newsletter. Based on teacher feedback, the original survey has been revised and will be used this year with ECCP students in the high schools.

ACTIVITIES APPROACH TO TMMW

A set of 103 activities have been developed with accompanying teacher's manual to allow teachers to offer a modified TMMW course to academically unsuccessful students. This set of materials is the output of this past summer's workshop of pilot teachers of this version of the course. Materials developed in the summer of 1970 were tested during the past school year and the new materials contain revision of old activities and new activities which will be tested in this coming school year.

The student activity sheets are available as black and white masters or ditto masters. A set of black and white masters of student activity sheets with accompanying teacher's manual costs $10.00 per set. The ditto masters of student activity sheets with accompanying teacher's manual costs $50.00 per set. The above prices only cover the reproduction costs of these materials. Those interested in obtaining these materials can order them directly from ECCP headquarters in Brooklyn, N.Y.

The authors of this set of materials feel that all high school students should be given the opportunity of learning about the characteristics, capabilities, limitations and impact of modern technology. The fact that students have poor reading and mathematical skills does not necessarily prevent them from developing technological literacy. The basic philosophy of this set of materials is that academically unsuccessful students can develop an understanding of the many dimensions of modern technology; provided that they are involved in activities which are fun and do not depend heavily on reading and mathematical skills.

Concepts and techniques are learned by performing meaningful and interesting activities. The idea of "learning by doing" is certainly not new. What is new is its use as the major vehicle for learning!

Approach

Most of the activities are designed to be completed in a single class period. Irregular attendance patterns of many non-academically oriented students make the sequential approach to learning almost impossible. With single-period activities, the probability of student success in an activity is enhanced if it doesn't depend too much on what went on the day before. Students who attend class regularly also profit because they get a more varied experience.

The student activity sheets are designed to be used *one at a time*. This allows students to focus their attention on one sheet at a time. Folders should be provided so that finished activities can be kept to provide the student as well as the teachers with information about what is being learned. Once in every week or two, guided reading lessons from TMMW text can be introduced after students have developed an interest in a particular idea.

Format of student activity sheets

Each activity begins with a student sheet which contains a boxed-in area which briefly discusses the reason for doing the day's activity. This is followed by a pictorial illustration of the topic under discussion. Some of the introductory sheets end with questions about the pictorial illustrations.

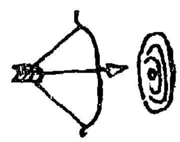
Subsequent sheets involve students in the major activity of the day which when completed results in understanding some aspect of one of the ten major ideas. Before using a particular set of activity sheets, it is imperative that teachers refer to the teacher's manual.

Format of teacher's manual

The teacher's manual is designed to help a busy classroom teacher make optimum use of the student activity sheets. Objectives are stated first and the strategy for achieving the stated goals are then discussed. Finally the required equipment, related resources and sample responses and/or data are listed. More specifically each activity has an accompanying teacher's manual which consists of six sections:

Pictorial description — **Verbal description**

(1) Umbrella Idea(s): The main purpose for doing the activity.

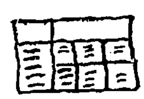


(2) Behavioral Objective(s): Specific goals which can be measured by student performance.

(3) Strategy and Approach: How to use the activity sheets to achieve the above purpose(s) and objective(s).

(4) Equipment: Materials needed for the activity.

(5) Resources and References: Material which provide enrichment, background and extension ideas.



(6) Sample Responses and/or Data: Suggested answers to questions and sample data for experiments.

Content

To study modern technology with its many facets would be impossible. This set of activities develops a generalized systems approach for the analysis of interactions which involve man and machine as well as technological systems and society. The activities are designed to teach ten major ideas:

(1) Matching technology to Man, Scoiety and Environment
(2) Elements of Decision Making
(3) Criteria and Constraints
(4) Systems Modeling (Functional & Descriptive)
(5) Optimization and Algorithms
(6) Analysis of Changing Systems
(7) Machines and Systems for Man
(8) Communication – Man to Man; Man to Machine; Machine to Machine.
(9) Building Blocks for Digital Computers (modeling with LCB)
(10) Impact of Technology on Man, Society and Environment.

There are also a few introductory activities which allow students to get a glimpse of the total course. This introductory section is designated as category (0). Category (11) provides supplementary materials. There are no reproduction masters for the activities in this category.

T. Liao

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TECHNICAL NOTE

These technical notes are written to indicate a few of the current frontiers of technology. These TN's are particularly designed to supplement the text material in THE MAN MADE WORLD, *the source developed by the Engineering Concepts Curriculum Project (ECCP), and at the same time to indicate a sampling of the broad range of interactions between technology and our daily lives.*

Single copies of the TN's are available from the ECCP office, Polytechnic Institute of Brooklyn, 333 Jay Street, Brooklyn, N.Y. 11201. Telephone (212) 643-5360. Teachers of THE MAN MADE WORLD *may obtain copies for their students.*

MAN AND HIS NUMBERS

Marana O. Thompson
Rad-Ex Syntactics Corp.

What is number? Number is a concept of quantity represented by written symbols called numerals. Numerical symbols vary from country to country, from age to age, from pictographs to alphabets. The numeration varies from the binary (base 2) to the sexagesimal (base 60) with bases of five, ten and twenty being the most common since man used his fingers and toes for counting. The number base is established when a fresh start in counting is made at a definite point. For example, when primitive man had progressed to indicating a number exactly, he expressed the number eleven as 'all the fingers and one more'; or, if he called five fingers 'hand', then eleven became 'two hands and one finger'. Mastering this elementary concept required many centuries of progress in man's struggle towards the abstraction of number from the many different objects it could describe. Recognizing that the word or symbol for 3, 4, 5 or 6 is only a verbal or written way of characterizing all possible sets of things of a certain type, illustrates the basic nature of what is called 'pure' mathematics.

Primitive counting

In man's early steps toward understanding numbers, he learned to match objects on a one-to-one basis. Instead of counting his sheep or cattle, he tallied them by cutting notches in a stick, tying knots in a cord or piling stones in a heap. This ability to recognize equal sets of objects, or to differentiate between two sets containing unequal numbers of objects, involves an innate instinct called 'number sense', but not the ability to count. However, it does reveal the germ of notation since the use of sticks, and the like, make tangible the numerical values.

As 'number sense' developed into simple counting, number words evolved which have a remarkable similarity in the various languages. The number words or vocal sounds were connected with finger-counting and, in the most primitive societies, were devices for connecting the real world with the supernatural.

Finger notation

In the absence of inexpensive writing materials, numerical representation by the position of the fingers and hands was used to retain numbers erased during the operations of the sand abacus and other such computers. Counting generally began with the little finger of the left hand, followed by the others in order. The right hand was reserved for the higher numbers. An outgrowth of this developed into a finger numeral language used in bargaining at fairs through the Middle Ages and is used today in isolated spots of Europe, South America and the Orient. (Fig. 1)

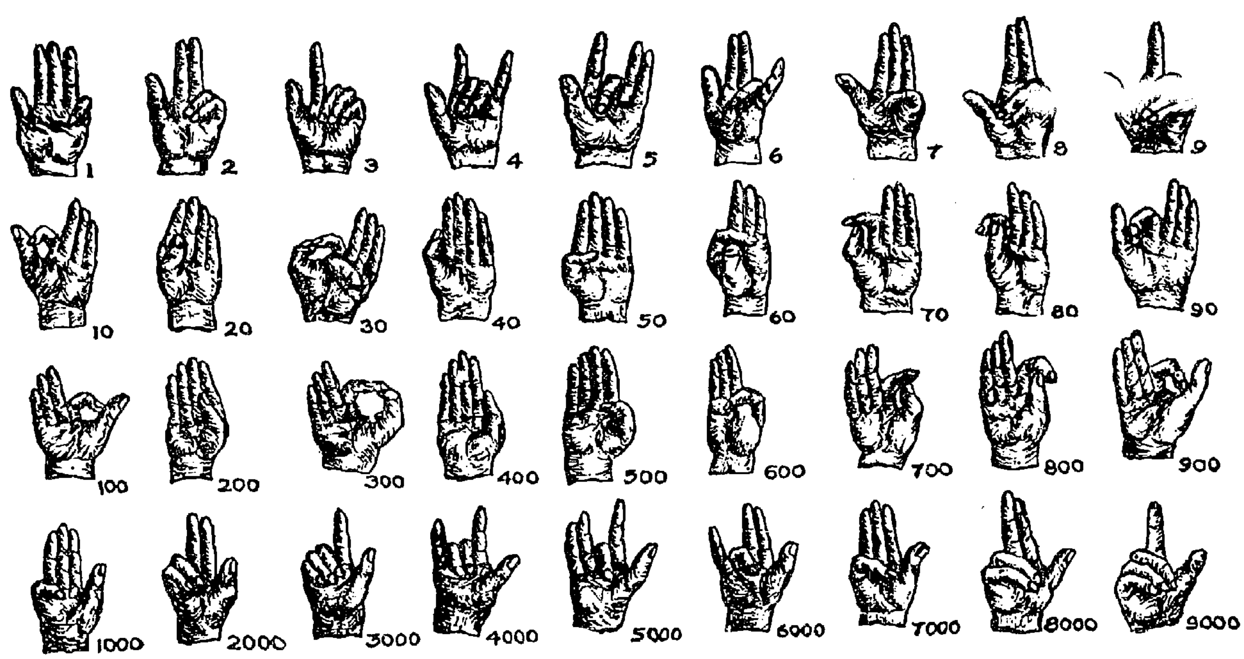


Fig. 1. Finger numerals (From a manual published in 1520)

Related to the finger numerals are the finger computations, of which 'Finger Reckoning', or the multiplication of factors between 5 and 10, played the most important part. This method made a knowledge of the tables beyond 5 x 5 unnecessary. The closed fist of each hand counted as 5; one finger extended, 6; two fingers extended, 7; three fingers extended, 8; four fingers extended, 9; all fingers extended, 10. One hand represents one factor, and the other hand, the second factor. For example, to multiply 8 by 6 (Fig. 2), the

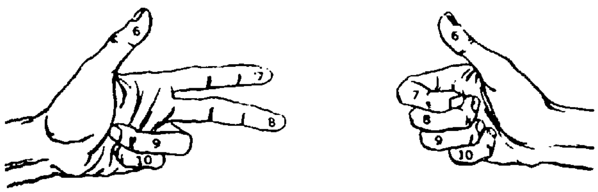


Fig. 2. Finger multiplication

left hand has 3 fingers extended, 5 + 3 = 8; the right hand has one finger extended, 5 + 1 = 6. The product of 8 x 6 has a 4 in the tens' place (each extended finger has a value of ten, 3 tens + 1 ten = 4 tens), and an 8 in the ones' place (each closed finger has a value of one, 2 ones x 4 ones = 8 ones). The result is 4 tens + 8 ones, or 48.

Although the reasons for the accuracy of this result may seem obscure, it is, in essence, one of multiplying by complements, and algebraic proof of the method's validity is possible. Numerous variants of the plan have been in use, some being brought to Europe from Arab schools.

Number symbolism

Along with finger counting as an expression of number goes the belief that certain numbers were 'good' or 'evil'. Of the 'good' numbers, three became all-encompassing and universally clothed in many meanings – the family and, by extension, the Holy Family and the Trinity; the physical world, Heaven, Earth and Water; early divisions of the year, Spring, Summer and Winter; the human life cycle, Birth, Life and Death. In short, three is the beginning, the middle and the end – a complete cycle.

The Babylonians developed an extensive number symbolism pertaining to astronomy and astrology in wh... number *seven* was endowed with good and evil in equal proportions. To combat its demons, magic incantations were repeated 7-fold, cords were knotted 7 times and 7 ears of corn were roasted. Having discovered 7 gods, 7 devils, 7 days and 7 winds, the astronomer sought long and diligently for 7 planets. Amazingly, he found them and sought no further. The 7 planets became the fate-deciding gods, and eventually, to rule the days of the week.

Numeration

The earliest numerals of which there is definite record were simple straight marks, either vertical or horizontal, for the small numbers, and some special form for ten. The number 'one' undoubtedly was represented by a vertical or horizontal stick or finger, | or – ; two was || or =, when written hurriedly || became N , or ⌐ , the symbol used by the Arabs and Persians. The = became Z, not unlike our 2, into which it may have developed. The three was ||| or ≡. Our three may be explained by the blurring of the pen into 3 , or the Arabic from W. The special position occupied by 10 stems from the number of human fingers.

Egyptian hieroglyphics

Beginning about 3400 B.C., the Egyptians used a simple grouping system for writing on stone known as hieroglyphs. The symbols stood for concrete objects, just as the words did. One was a vertical stroke, ten a heelbone or arch, 100 a coil of rope or scroll, 1000 a lotus flower, 10,000 a bent line, 100,000 a burbot (fish) or pollywog, 1,000,000 a man in astonishment at so large a number. (Fig. 3). Since the

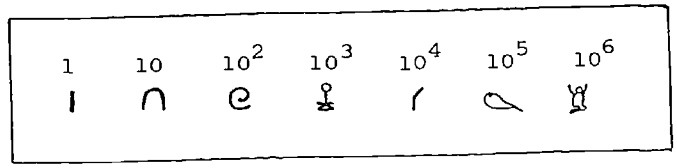


Fig. 3. Egyptian hieroglyphic numerals

Egyptians usually wrote from right to left, they would have written the number, shown in Fig. 4, as 243,688 = $2(10^5) + 4(10^4) + 3(10^3) + 6(10^2) + 8(10) + 8(1)$.

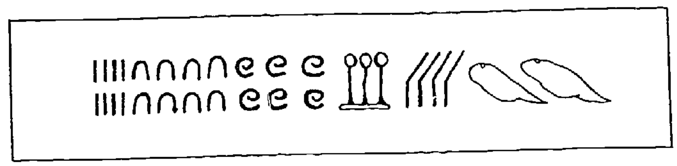


Fig. 4. Egyptian hieroglyphic number

Cuneiform numerals

The Babylonians impressed their symbols in damp clay tablets with a stylus, and then baked them in the sun or in a kiln. The symbols could be made with either the pointed or the blunt end of the stylus. Fig. 5 shows the two forms.

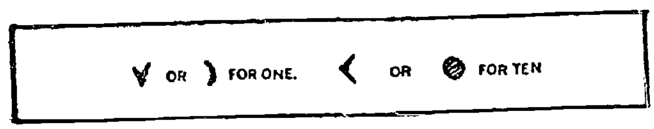


Fig. 5. Cuneiform symbols

For numbers up to 60, these symbols were used in the same way as the hieroglyphs, except that a subtractive symbol was also used (Fig. 6). ... the cursive... ear numerals occur together ... some documents from about 3000 B.C. The two types were used to differentiate

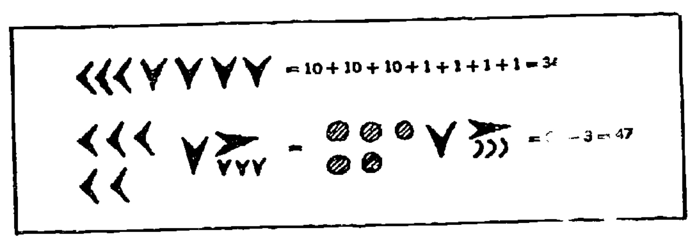


Fig. 6. Cuneiform numbers

recorded data; for example, wages already paid were written in curvilinear, and wages due in cuneiform.

Although the Babylonians did have a positional notation, it suffered from the lack of a zero symbol. They left a blank space which tended to disappear in the interests of recording a number compactly. Also, since their base 60 was large and cumbersome, they resorted to a simple grouping system to base 10 for numbers over 60.

Greek numerals

Besides the primitive plan of repeating single strokes, the Greeks had two important numeral systems. Their first elaborate system, known as the Attic numerals, was influenced by their alphabet, and was based on the initial letters

Π OR Γ, PI, FOR ΠΕΝΤΕ (PENTE), 5
Δ, DELTA, FOR ΔΕΚΑ (DEKA), 10
H, AN OLD ATTIC BREATHING (h) FOR HEKATON (HEKATON), 100
X, CHI, FOR XIΛIOI (CHILIOI), 1,000
M, MU, FOR MΥPIOI (MYRIOI, MURIOI), 10,000

ΓΔ OR ΓΔ, PENTE-DEKA, 5 × 10, OR 50
ΓH, PENTE-HEKATON, 5 × 100, OR 500
ΓM, PENTE-MURIOI, 5 × 10,000, OR 50,000

Fig. 7. The two Greek numeral systems

of the numeral names. These initial numerals are shown in Fig. 7.

About the 3rd century B.C., the second system, known as the Ionic ciphered numerals, came into use. This one was based also on the initial letter system, but better adapted to the theory of numbers and more difficult to comprehend, as it required memorizing 27 characters, their own 24 letter alphabet plus 3 obsolete forms, plus accent marks to distinguish numbers from 1,000 to 9,000 from 1 - 9.

Other ciphered numeral systems include the two later Egyptian ones, the Hieratic and the Demotic, used for writing on clay or papyrus; three alphabetic systems, the Hebrew, Syrian and early Arabic; the Coptic and the Hindu Brahmi.

Roman numerals

Since the Romans influenced the known world for a long period of time, it is not surprising that their numerals, simple but greatly superior to other systems then existing, maintained a strong position in Europe for nearly 2,000 years. For the general user, its chief advantage was that it required memorizing only 5 values – I (1), V (5), X(10), L (50) and C (100). An additive and subtractive place principle was employed to combine three symbols into numerals. It is much easier to see three in III than in 3, and to see nine in VIIII (later IX or unus de decemi) than in 9, and correspondingly easier to add since addition combinations did not have to be committed to memory. By the same reasoning, it is also easier to subtract as like numbers can be canceled; for example, V subtracted from VIII = III. Multiplication is clumsy and unwieldy (Table II), but still simpler than memorizing our multiplication tables.

As with other notations, the larger numerals were developed or evolved from modifications of the earlier Greek letters. 'Theta' θ (see Table I) selected for the Greek 100, changed to C under the influence of the word 'centum' (hundred); and 'phi' Φ (Greek 1,000) gradually became (I) with the right half becoming I) or D for 500. The Romans also used M for 1,000 from the word 'mille' (thousand), later $\overline{M}$ for million (1,000 x 1,000) and |M|

Table I. Ionic Greek ciphered numeral system

	1	2	3	4	5	6	7	8	9
UNITS	A	B	Γ	Δ	E	[F]	Z	H	ϴ
TENS	I	K	Λ	M	N	Ξ	O	Π	[Q]
HUNDREDS	P	Σ	T	Υ	Φ	X	Ψ	Ω	[S]
THOUSANDS	/A	/B	/Γ	/Δ	/E	/[F]	/Z	/H	/ϴ

Table II. Roman numeral multiplication

×	I	II	III	IV	V	VI	VII	VIII	IX	X
I	I									
II	II	IV								
III	III	VI	IX							
IV	IV	VIII	XII	XVI						
V	V	X	XV	XX	XXV					
VI	VI	XII	XVIII	XXIV	XXX	XXXVI				
VII	VII	XIV	XXI	XXVIII	XXXV	XLII	XLIX			
VIII	VIII	XVI	XXIV	XXXII	XL	XLVIII	LVI	LXIV		
IX	IX	XVIII	XXVII	XXXVI	XLV	LIV	LXIII	LXXII	LXXXI	
X	X	XX	XXX	XL	L	LX	LXX	LXXX	LXL	C

(100,000,000). (See Fig. 8, the late Roman Abacus or "pocket calculator"). Illustrating the Roman use of repetition, the "Columna Rostrata", a monument to the victory over the Carthaginians in 260 B.C., has the symbol (((I))) for 100,000 repeated 23 times, making 2,300,000.

Ultimately, most calculations were done with counters on a counting board or abacus. The counters, calculi (pebbles) from which our word calculate stems, were pushed up on the board to figure the number sought, and then the numerals were recorded. This method was quite adequate for everyday computations long after the introduction of Hindu-Arabic notation.

Chinese numeral systems

The Chinese numeral systems are the principal examples of multiplicative grouping, 4 variants are shown in Table III. In multiplicative grouping, special names designate 1, 2, 3, . . . , 9) in the usual way, but 10, 100 and 1,000 also have special names which are used in place of repetitions of the first set. For example, if we replace 10, 100 and 1,000 by X, C and M respectively, we would write 8,473 as 8M4C7X3. The later systems, Modern National and Mercantile, are positional and use a circle for zero.

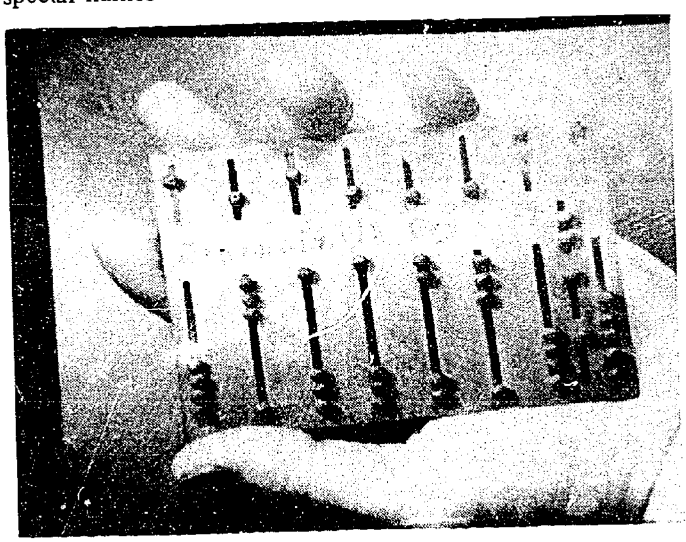


Fig. 8. Late Roman abacus

The concept of zero

Neither the Mayan nor the Babylonian system was at all suited to arithmetical computations because the digits – the numbers less than 20 or 60 – were not represented by single symbols. To the Hindus must go the credit for expressing all numbers by means of 10 symbols, and for the introduction of zero. The use of a place holder to mark that power of a base not actually occurring was indicated with a dot or small circle, called 'sunya', from the Sanskrit word for vacant. About 800 A.D., the Arabs translated 'sunya' into the Arabic 'sifr' but kept the meaning intact. Eventually, 'sifr' was transliterated into Latin where it retained the sound but not the meaning. Today, we use the word 'cipher' in a capricious way, sometimes it means zero and sometimes any Hindu-Arabic numeral; in the verb form, 'to cipher', it means to compute.

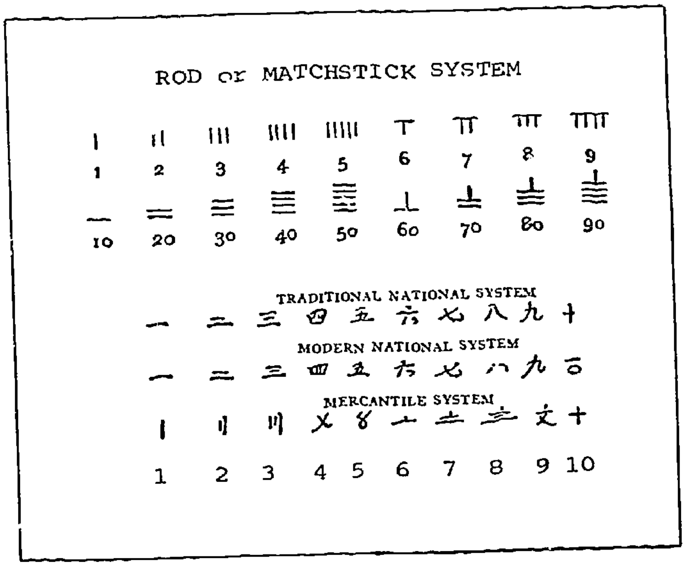
Hindu-Arabic numerals

The essential features of the Hindu-Arabic system are distinct symbols for all the integers from 1 through 9, plus a unique symbol for zero, 0. Its greatest advantages are that each symbol has a value which depends upon its position in the number to indicate units, tens, hundreds, and so on, as well as its absolute value. This gives us a number system which makes possible the concise writing of very large numbers, stretching out to infinity in either direction.

In the early years of use of the Hindu-Arabic numerals, it was not uncommon to combine them with Roman. An example, shown in Fig. 9, explains the Hindu-Arabic system by the use of Roman numerals; note that the decimal fractions are given as a logical extension of the Roman system.

By the middle of the 18th century, countercasting as a means of reckoning was virtually defunct. Thereafter, the Hindu-Arabic numerals and the base 10 were accepted not only in Europe, but throughout the world. The decimal system comes as close to being a universal language as man has devised so far.

Table III. Chinese numeral systems



The binary positional system

For calculations, the decimal system with its perfected positional notation has eliminated most of the difficulties inherent in the older systems, except for one island in present day life: the electronic computer. Here, the binary positional system has greater advantages over the decimal. In the binary system (base 2), there are only two digits, 0 and 1; 2 becomes 10, since it plays the same role as does 10 in the decimal system. The year 1971 would appear as 1 11101 10011. The binary number is longer because it distinguishes between only two possibilities, 1 and 0, instead of the ten possibilities in the decimal system. This means that the binary digit carries less information than the decimal digit. For this reason, binary digit has been shortened to bit; a bit of information is thus transmitted whenever one of two alternatives is realized by the computer. It is much easier for a machine to pick one of two choices than one from 10, another advantage of the base 2; a more important point is that bits carry numerical information and the logic of the problem simultaneously. Just as the decimal number for the year 1971 = $(1 \times 10^3) + (9 \times 10^2) + (7 \times 10^1) + (1 \times 10^0)$, the binary equivalent 1 11101 10011 = $(1 \times 2^{10}) + (1 \times 2^9) + (1 \times 2^8) + (1 \times 2^7) + (0 \times 2^6) + (1 \times 2^5) + (1 \times 2^4) + (0 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0)$ multiplying the powers of two and adding them gives the value of the number:

$1024 + 512 + 256 + 128 + 0 + 32 + 16 + 0 + 0 + 2 + 1 = 1971.$

To convert a whole decimal number to its binary form,

NUMERATION

Teacheth to read or write any number proposed either by words or characters, according to the following

TABLE

6	5	4	3	2	1		2	3	4	5	6
C. M.	X. M.	M.	C.	X.	Units	.	X. parts	C. parts	M. parts	X. M. parts	C. M. parts

Roman numerals used to explain the place values in Hindu- (From Leybourne's "Cursus Mathematicus", 1690)

repeated division by two is used until a quotient of 0 remains. The remainders, either 0 or 1, are the digits of the binary number reading from right to left away from the binary point. In the following example, the number 123 is divided into its binary form:

(1) $123 \div 2 = 61$; $123 - 122 = 1$ (2) $61 \div 2 = 30$; $61 - 60 = 1$ (3) $30 \div 2 = 15$; $30 - 30 = 0$ (4) $15 \div 2 = 7$; $15 - 14 = 1$ (5) $7 \div 2 = 3$; $7 - 6 = 1$

(6) $3 \div 2 = 1$; $3 - 2 = 1$ (7) $1 \div 2 = 0$; $1 - 0 = 1$

Then, reading from right to left, the binary number is 11 01111. In writing binary numbers, a space is left after every fifth digit to the left or right of the point. Conversion in the other direction using decimal arithmetic is easiest with a decimal table of powers of 2, (Table IV).

Man-machine numerals

With the advent of computers to remove the burden of calculation, much as the abacus did, we require symbols only to represent the results of those calculations. However, if the computer could "understand" the same symbols as the man operating it, efficiency would benefit considerably. That is, having to translate numerical input information into "computereze" (binary notation) for machine use, and then reversing the process so that the output results in a comprehensible form to the operator, is not efficient. This situation prompted us to search for a new symbology compatible with both man and machine. Guide lines were simple: the numbers must be binary in nature; but, by arrangement, create the illusion that the familiar decimals, 0 through 9, are being viewed.

The basic computer

A brief explanation of the basic computer may help to visualize the computer-man problem. For illustration purposes, this discussion will be confined to a computer operating in the base 10. Broken into decades, a computer consists of a series of scalers, each dividing the incoming pulses into groups of ten, and then passing a single pulse to the next counter. Looking inside each scaler, you find four identical flip-flops, synonymous with four toggle switches. An incoming signal is processed as follows: (Fig. 10) square waves are fed to the first of a series of 4 flip-flops (FF). Successive pulses cause the first FF to change state in rhythm with each pulse. The second FF switches only once to every two state changes of the first FF. Four changes of state of the first FF are required to flip the third unit and eight to flip the fourth unit. If this process were allowed to continue freely, fifteen counts (called Hexadecimal) would be necessary to bring all FF to state "1". The 16th pulse would return all FF to state "0". However, this does not fit the decade system, therefore special circuitry is required to return all FF to state "0" after the 9th count. The arrangement of 'bits' to count 0 - 9 is called Binary Coded Decimal. (See Table V, BCD column). If lamps were tied to the outputs of a decade system as described, an illuminated BCD pattern would result and, as a matter of history, was used on the first electronic frequency counters. (Fig. 11). The prospect of having to read large numbers in BCD defeated the staunchest souls; for instance, 9,999,999 = 28 lamps, 7 groups of four. Therefore, various means to decode BCD into a more readable language were devised quickly. Simultaneously, a means of talking to the computer in its binary tongue was destroyed.

Our search for a number system was based directly on this proposition that some four lamp arrangement must be possible which would be acceptable, logical and pleasing to man, and also avoid decoding the BCD contained in the scaler. Once found, we recognized a reversible glyph had

Table IV. Binary to decimal conversion

Binary	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Decimal	1024	512	256	128	64	32	16	8	4	2	1

been created. Not only did our character display easily without decoding, it also had the unique characteristic of being machine readable without encoding. Two other properties which make this symbology an excellent candidate to replace the Hindu-Arabic style, lie in its relation to the exponential powers of two (see Binary Positional System), and its pictorial mechanization of arithmetic (see Appendix).

RAD-EX numerals

The name of our numerals is derived from '*ex*ponents of the *rad*ix 2'. As explained in the preceding paragraph, the most significant features of this numeral are its binary nature, and its ability to be read by man or machine easily. Consequently, we felt that the name should represent what it is, a man-machine interface.

With a single vertical stroke, the basic unit "one", ı, is represented. A single horizontal bar represents the numeral "four", —. All the remaining numerals are combinations of these two basic symbols. (See Table V). An operator is "trained" to recognize these symbols in about five minutes of explanation and familiarization.

Perhaps most important is the humanizing of arithmetic. Research studies have established that the great majority of people hate arithmetic, and that this attitude is developed very early in the educational system. Young minds are quite literal and imaginative. However, imaginative conceptions and abstract thinking can not be equated. Here is where irreparable damage is done to the child and lasts a life time.

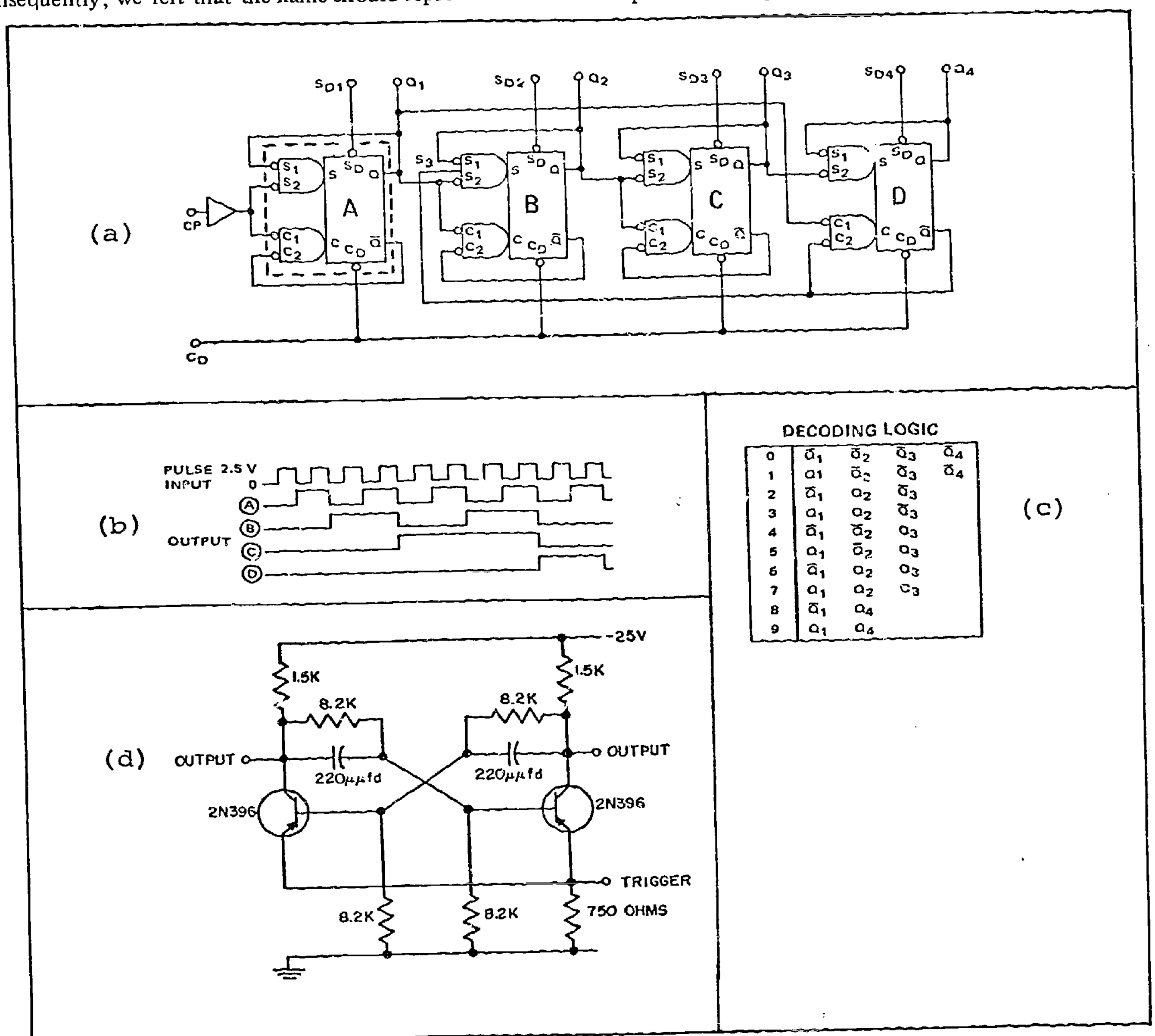


Fig. 10. (a) Decade counter – dashed lines enclose one flip-flop, (b) square waves show changes of state in consecutive flip-flops, (c) decoding logic of decade counter, (d) typical circuit of one saturated flip-flop.

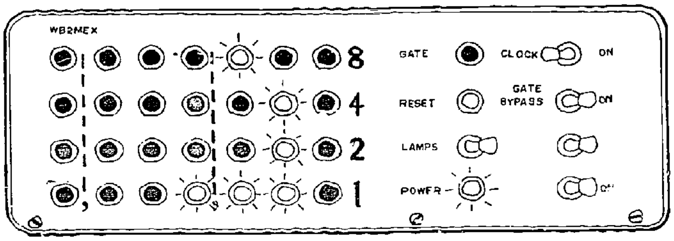


Fig. 11. First BCD frequency counter number shown is 1970

What we are beginning now to see as economic chaos starts at this point. Economics is based on simple arithmetic, yet we have produced a nation incapable of doing the simplest number mechanics. 1970's international mathematics contest, won by the Japanese with a resounding score, is an example. The Jananese teeche on the abacus. The two important associations with the use of the abacus are:

1) its pictorial representation of a number,
2) its extensive use of complements.

Imaginative concepts of numbers are extremely important and, since the beads represent tangible, real objects, the Japanese see quantities as concrete bits. The second, complementing, makes columns of addition positive, and avoids the negative aspect of subtraction.

How do RAD-EX numerals fit this arithmetic problem? First, they are pictorial, 0 = I̲I , 1 = I , 2 = II , 3 = III̲ , 4 = ..., (for speed writing, this becomes a horizontal bar —), 5 = T , 6 = TT , 7 = TTT , 8 = ⋮⋮ and 9 = ⋮I⋮ . Essentially, this establishes a one-to-one concept of quantity, Fig. 12. This is vastly different from translating 5 into five sticks (IIIII) and 2 into two sticks (II), and then come up with a sum (IIIII + II) = 7 sticks. Here, a child has been commanded to memorize totally unrelated shapes. Even if he is told that this is reasonable and logical, his own ability to reason and apply basic logic says it is not. To compensate for this illogical language, the child is given "drills" to work on with the advice that "if he does his drill work, he will comprehend the problems", further insulting his intelligence! Right here is where some of the most creative children lose interest permanently, to say nothing of the adults who should understand arithmetic better than they do. Only recently has this situation become apparent, and hopefully, adoption of this number system may correct the problem.

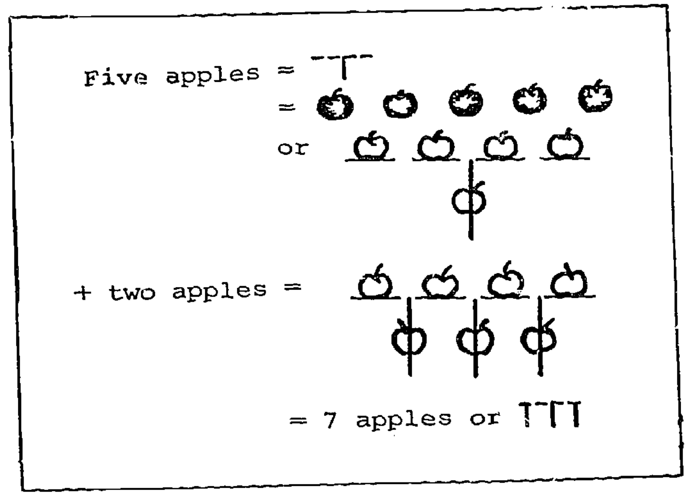


Fig. 12. RAD-EX addition

In a more advanced sense, RAD-EX numerals not only fit simple arithmetic, but also may be used as a simple bar code, since its characters are easily hand written and computer read. The interrelationships connect the notation directly to the Binary Coded Decimal notation used by the computer to 'talk' to man. (See Table V). A computer can treat these bars as weighted information by assigning a value of 'one' to all vertical members, and a value of 'four' to all horizontal members. This machine reading is accomplished with two photocells, one, scanning the number field horizontally, picks up ones and stores them in the first two flip-flops of a decade system; the second, scanning vertically, picks up fours and stores them in the last two flip-flops of a decade counter. (See Fig. 13). The decade counter is now loaded with a BCD character which may be used by any computer.

Table V. Decimal, BCD, RAD-EX comparison

Decimal	BCD				RAD-EX
	2^3	2^2	2^1	2^0	($2^3 = 2^=$, $2^2 = 2^-$, $2^1 = 2^{II}$, $2^0 = 2^{I}$)
0	0	0	0	0	I̲I
1	0	0	0	1	I
2	0	0	1	0	II
3	0	0	1	1	III
4	0	1	0	0	—
5	0	1	0	1	T
6	0	1	1	0	TT
7	0	1	1	1	TTT
8	1	0	0	0	=
9	1	0	0	1	I̅ (=I)

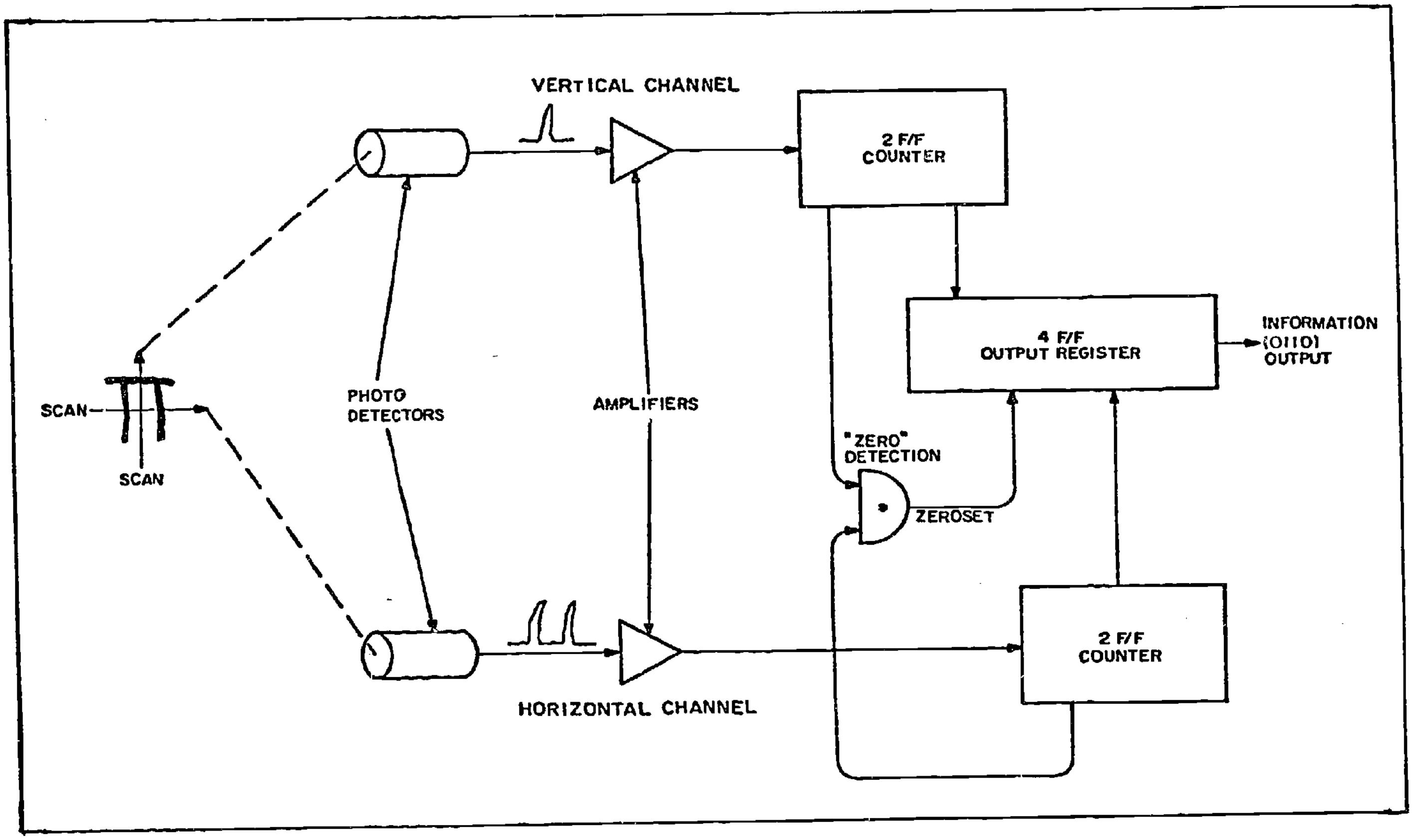


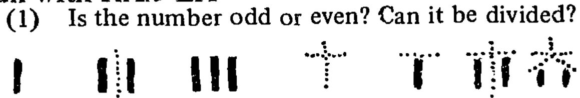
Fig. 13. Dual-scan character recognition

Conclusion

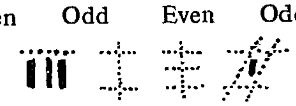
In retrospect, man is a mechanically oriented animal. The joke about the shop giving a machined part to a draftsman so that he can make drawings is much more truth than fiction. Fire, gravity, flight, rocket propulsion, and so on, are the results of man busily imitating nature and experimenting mechanically. Gradually, mathematics have been applied, and the results man has achieved have become much better. Undoubtedly, man will remain the mechanical experimenter; therefore, it is logical to provide him with a mechanical number system which fits his nature.

Appendix
Fun with RAD-EX:

(1) Is the number odd or even? Can it be divided?



No Odd — Yes Even — No Odd — Yes Even — No Odd — Yes Even



No Odd — Yes Even — Yes Odd

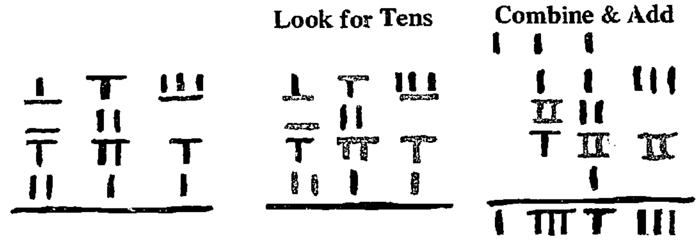
A student can visualize the division process mechanically. Try doing this stunt with 6 or 8. Is it possible?

(2) A combination of numbers which add to ten is most useful. To find the complements of ten: Black = number, orange = complement.

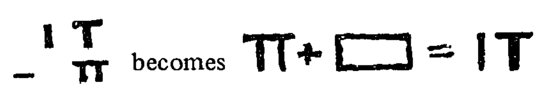
(Many basic principles in mathematics are recognized through general agreement, such as $2^0 = 1$; thus II = zero must be simply a rule of agreement also.)

(3) The above knowledge becomes a powerful tool in the addition problem shown below: Black = number, orange = complements, blue = carries.

Look for Tens — Combine & Add

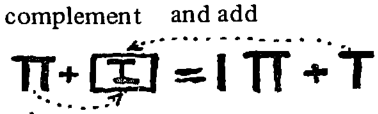


(4) What occurs in subtraction? Here, something is appended to a small number to get a predetermined larger number. A problem written conventionally is transposed from subtraction to addition:

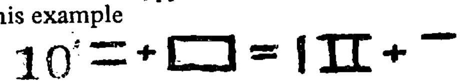


or in a balanced equation

Now use the complement and add



Try this example



TEACHER'S INSTRUCTIONAL MATERIALS

The packaging of teacher materials for any course is a problem in optimization. The major criterion of the authors is to make the materials as useful and convenient as possible for the majority of teachers.

The wealth of materials in THE MAN MADE WORLD Teacher's Instructional materials is the result of discussions with hundreds of teachers during the first five years of the Engineering Concepts Curriculum Project.

The instructional materials include the following:

(1) The soft cover book containing the minimum teacher material needed to effectively teach the course. (Teacher's Manual)

(2) A package of black and white masters for worksheets and/or transparencies.

(3) Feedback Instruments (formerly called tests).

(4) Miscellaneous Items

(a) Tape cassettes to encourage a variety of instructional patterns.

(b) Observation check list masters for use in recording observed behavioral changes.

(c) Equipment maintenance details packed with all major pieces of equipment.

The items (2 through 4) will be changed in number and emphasis as implications of technology and society dictate such updating. This is a part of the continuing program of support for teachers.

Teacher's Manual

This manual is organized into chapters to parallel the text. Each chapter is then organized into sections as follows: (1) Approach including objectives, (2) Black and white masters, (3) Cues (answers to discussion, questions, and problems), (4) Demonstrations and laboratory hints for the teacher, (5) Evaluation (keyed to objectives and performance levels), (6) Film notes, (7) General including bibliography.

The first page of each chapter contains a check list which should be studied prior to teaching the chapter. This check list indicates not only how much time most teachers spend on each section of the chapter, but also which transparencies, demonstrations, films, discussion questions, problems, and quiz questions apply to each section.

A. Approach
The approach to each section is described in some detail. This is an important section since the ECCP approach is often quite different from that of conventional science, mathematics or social science teaching. It is this approach which gives TMMW its distinct flavor as an interdisciplinary course which is particularly effective with non-science students. One vital facet of the approach throughout the course is the emphasis on student laboratory, group discussion rather than lecture, and the presentation of problems as motivation prior to the development of concepts.

B. Black and White Masters
Much of the development of the course content relies on discussions which involve diagrams of some sort. Rather than having you laboriously drawing these diagrams on the chalkboard, the TM package furnishes black and white masters from which transparencies can be made on copying machines in your school. Some of these diagrams are quite useful as student worksheets, e.g., routing police cars. This constitutes a saving of some three hundred dollars compared to other courses using the same number of transparencies. The TM has small reproductions of these transparencies which are reproduced in full size in the Transparency Set.

C. Cues
This section has cues to the use of discussion questions and problems. Suggestions as to the timing of these questions and problems are made in the check list. Emphasis is on the approach to the answer rather than on having each student give the same answer to a given question.

D. Demonstrations and Laboratory
This section explains the use of existing laboratory experiments and demonstrations, and suggests additional activities with the normal equipment of the course as well as with supplementary equipment usually found in high school science laboratories.

Typical but not all-inclusive answers to the marked laboratory questions are given. These are guides. There are additional answers some students will give which are just as appropriate and which must be considered in the light of your own experience during the laboratory period.

E. Evaluation
The items in the bound sections are samples which may be copied, modified, or discarded as you wish. They are neither mandatory nor all-inclusive.

F. Film Notes
While the ECCP has not made films specifically for the course, the staff has reviewed many commercially available films and has written film notes for those which apply most directly in approach and content to the objectives of the course.

G. General including Bibliography
Much of the revision of TMMW course during its five-year trial period included the elimination of some material as well as the expansion of other material. Some of the material was eliminated because it was considered too difficult for most students. Many teachers felt that this material was excellent background enrichment material for teachers and it is therefore included in this section of the Teacher's Manual.

While outside readings are vital to the complete presentation of the approach and content of the course, the inclusion of detailed bibliographies in the text is found by many teachers to be unnecessary. The detailed bibliographies are therefore listed in this section of each chapter of the Teacher's Manual.

Availability of materials

The teacher's manual for the new text with the accompanying black and white transparency masters will not be available for distribution until December 1971. The projected cost is between $16.00 and $20.00 per set. Those interested in purchasing these materials should contact Webster Division of McGraw-Hill Book Co. directly.

In the meantime, McGraw-Hill Book Co. has agreed to distribute the first five chapters of the teacher's manual, at no cost to all teachers who are teaching the course with the new text. Write Fred Boyd, if you want to receive the above mentioned materials: Fred Boyd, Webster Division, McGraw-Hill Book Co., Manchester Road, Manchester, Missouri, 63011.

A set of six feedback instruments consisting of multiple-choice and essay questions is currently being standardized and will be available from McGraw-Hill in January 1972. Two new cassette/workbook modules for individualized usage of the analog computer will be available in the fall. Next month's bulletin will describe these materials in more detail. The first cassette/workbook module on the introduction to analog computer usage is still available for $6 per set from project headquarters.

E. J. Piel

LEADERSHIP PREPARATION INSTITUTE FOR ECCP

Ruth Irene Hoffman
University of Denver

Twenty-six participants from twelve states representing fifteen urban centers have attended two conferences at the University of Denver, and have completed the first phase of the overall goal of the Leadership Preparation Institute.

The goal of the entire program is to establish satellite centers for implementation of ECCP, including dissemination of accurate course definition, active participation by school personnel from all levels, and localized teacher training.

Twelve teams have submitted detailed plans for conducting an Information Awareness Conference for school administrators in their regions. These are complete outlines containing statements of objectives for their conferences, a list of possible participants, schedules of dates and location, outline of activities, sources of supports, staff, and evaluation procedures.

Two teams have submitted proposals for support of summer institute programs (University of Utah and University of Pennsylvania) to the National Science Foundation.

Ma participants attended an updating session on the new text, *The Man Made World* in August, with Dr. Joseph Piel conducting the sessions with assistance from the local staff.

The conference sessions at Denver are themselves models for the participants to emulate in their own planning. They are organized for maximum involvement and interaction. For example, in the conference of September 16, 17, participants examined the elements in a *Temporary Social System* and then constructed models for such a system, which in turn were used for critical evaluation of the plans for the Information Awareness Conference submitted by the twelve teams.

During the academic year 1971-72, the teams will be conducting an Information Awareness Conference for school administrators, planning local inservice programs for teachers, and in some cases, actually conducting the inservice programs.

In order to pace the activities for the participants in their preparation for the role of "teachers of teachers", all participants have a work check list which they are following. The check list follows.

The participants are a dynamic group and besides their work load given right, have taken part in many modeling and learning activities themselves. If you know any of the participants, you might ask them to show you "Petals-Round-a-Rose", a most enlightening learning activity.

Date to be completed	Work to be completed	Work completed
July 1 1971	Preliminary version of team plan for Information Awareness Conference submitted to Director for staff review.	
July 15	Plan for Information Awareness Conference returned to participant teams with critical review of staff.	
Aug. 15	Revised team plan for Information Awareness Conference submitted to Director. (Should be typed for easy reproduction, if possible.)	
Aug. 30	Reproduced copies of all team plans distributed to all participants.	
Sept. 15	Read all team plans for Information Awareness Conference before second conference.	
Sept. 16-17	Attend second conference at University of Denver. (Group review and feedback on plans)	
Nov. 15	Preliminary version of team plan for ECCP Teacher Education Program submitted to Director for staff review (NSF Inservice, CCSS, Local Inservice, etc.)	
Dec. 1	Plan for Teacher Education Program returned to Participant teams with critical review of staff.	
Dec. 15	Revised team plan for Teacher Education Program submitted to Director. (Should be typed for easy reproduction, if possible.)	
Jan. 1, 1972	Reproduced copies of all team plans distributed to all participants.	
Jan. 28	Read all team plans for Teacher Education before third conference.	
Jan. 28-29	Attend third conference at University of Denver. (Group review and feedback on plans)	

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