AN EXPERIMENT IN MNEMONIC IMAGERY IN ADULT BASIC EDUCATION SCIENCE INSTRUCTION

BY

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ABSTRACT

AN EXPERIMENT IN MNEMONIC IMAGERY IN ADULT BASIC EDUCATION SCIENCE INSTRUCTION

This study was designed to investigate the effects of instructor provided mnemonic imagery on the learning of science content and problem solving. The experiment was conducted with adult basic education students(N=40). A number of visual anagrams were constructed which provided both the content and application of science rules. Mnemonic imagery instruction resulted in significantly higher performance on both formula recognition and multi-step problem solving tests.

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INTRODUCTION

There you are, in front of your class, reviewing a problem, when from the back of the room comes "The Question". What question you ask? You know, "the question". If you have heard it once, you have heard it a thousand times. "The question" goes something like this: " Do we have to remember this for the test?"

Why this great concern with remembering? As an instructor, what can I do to make the remembering task less arduous? Many of my Adult Basic Education students have already had less than positive experience with conventional teaching methods, yet they find themselves back in school upgrading their skills to compete in the new global economy. What new information skills must be imparted to them in order for them to compete?

Information at hand is vast and continually changing. We, after all, are in the information age. Technology is changing at an astonishing rate. The two-thousand dollar home computer of a couple of years ago has depreciated to the two-hundred dollar relic of today that will no longer run many of the new programs available. Just when I had finally mastered D.O.S. I find that D.O.S. is dead. It has become nearly impossible to keep up with technology with so much information at hand. Do we need to remember anything at all?. The answer is yes, of course. The ravages of memory loss make this all too apparent. Without memory, we cease to be the people we are. That is why even momentary losses in memory can be so disturbing. We all have had the frustration of forgetting where we have put our keys or the embarrassment of forgetting someone's name.

For the most part these momentary lapses in memory are no more than a minor annoyance. For a student writing an exam, the level of annoyance can be much greater making memory improvement a more pressing concern.

Will there come a day when all we will have to do is take a pill and we will no longer have to worry about momentary memory loss. Wilsher (1987) results suggest an increase in fluency of retrieval of words learned during treatment with nootropic drugs for dyslexic children. Girugue and Sars (1978), in an animal research study, reported that the nootropic drug, piracetam, is capable of reversing memory deficits particularly at retrieval level.

Clincke and Tritsmas (1987) report positive results using R 58 735 on encoding, consolidation and retrieval in verbal declarative memory tasks. The process of finding drugs that will improve memory in humans is not an easy one. The rather limited cognitive capacities of animals limits the predictability of the effects of drugs on more complex human cognitive abilities. Millar (1987), notes that effects of drugs can be inconsistent as they may effect more than one process. This echoes Girugue and Sara (1978) concern that pharmacological agents will act selectively on cortical plasticity without directly affecting motivation, locomotor activity or perception.

For many people, the idea of taking a pill for memory improvement in normal subjects is not appealing. A more holistic approach to memory improvement must consider other means of improving memory. Studies by Oakhill (1987), Marks and Folkord (1987) and Matthews,Jones,Chamberlain(1987) all found the memory is effected by the time of day. Such studies suggest that certain types of material are better taught at certain times of the day and that study might be more effective at different times of the day. As an engineering student, I was told that eating a meal before a test would inhibit performance. Smith (1987) found that performance was unaffected by breakfast but meals in the middle of the day and night did have an impairing effect on working memory tasks. Memory aids, mnemonics are also another means of improving performance on memory tasks.

The use of mnemonic process is a natural one. Surveys have shown that university students often use mnemonic devices for memorizing information connected with their course work.

Gruneberg (1973) found that students often used memory aids, mnemonics, for memorizing information connected with their course work. Carlson, Kincaid, Lance, and Hadgson (1976) reported higher scholastic performance among students who spontaneously used mnemonic devices in learning a list of words. Students who used mnemonic devices had a mean grade point average of 2.80, whereas those that did not use a mnemonic device had a mean grade point average of 2.37.

Memory Aids

Higbee (1977) refers to mnemonic devices as rather unusual, "artificial" memory aids, such as narrative stories, acronyms, rhymes, verbal mediators, and visual imagery. This rather narrow view of mnemonic devices is found in many popular memory training books.

The definition of a mnemonic device is not a precise one. A wide range of memory aids are considered mnemonic devices. Bellezza (1981) describes a mnemonic device as anything from tying a knot in a handkerchief to organizing all human knowledge by storing it in symbolic form among the rows and aisles of a vast imaginary theatre, as Camilla attempted to do in the sixteenth century. Mnemonic techniques can be divided into two basic categories, internal and external techniques.

Internal techniques are those which go on inside the mind of the user. These are considered your typical mnemonic devices. External techniques are commonly used but often not thought of as a memory device. These techniques are anything outside the mind of the user. In Bellezza (1981); Greenberg and Powers (1987); Biermann (1989); Ward (1988) and Harris(1978) a variety of internal and external techniques were discussed.Internal aids included (a) acronyms (first letters),(b) face-name method,(c) key word method,(c) link method,(d) loci method,(e) peg or hook method,(f) phonetic method,(g) reconstructive elaboration, (h) rhymes and (i)Yodai.External aids included (a)alarm watches with rate on back,(b)asking someone else to give you a reminder,(c)boxes around important diagrams,(d)calendars,(e)computer disk,(f)cue cards,(g) high lighting text,(h) labels on item,(i) string on finger,(j) watch on the wrong wrist,(k) fingers on hand,(l) folded piece of paper,(m) tape recorder,(n) two hands,(o)make list,and(p) schedules.

We will start by dealing with the latter list, that of external memory aids. People without memory impairment, make frequent use of external aids (Wilson ,1993). These techniques have also received much consideration from those dealing with head injury patients. External memory aids are probably the most important means of compensating for memory deficit. Given this fact, Wilson (1993), considers it worthwhile for therapists, teachers, and relatives to investigate as wide a range as possible, and to be prepared to put considerable effort into teaching the use of such aids. Unfortunately, one of the biggest problems with external aids is that many patients are reluctant to use them. The belief that aids are a means of cheating and should not be relied on should be discouraged. There is no evidence to suggest that using aids will result in less recovery of memory (Wilson ,1993, p 470). In fact, it may result in more efficient use of memory skills the person does possess. In fact, those memory impaired patients, using six or more memory techniques, are more likely to be independent.

External Memory Aids

Kapur (1993), describes an external memory aid as being some portable device used by an individual, which may act as a memory aid. This is a much more precise description of an external memory aid than that can be inferred from the examples of external memory aids given by many other authors. Harris (1978) include clues which have been created for the users environment as an external aid. Kapur (1993) considers environmental memory aids as a separate class within the realm of external memory aids. The list of external memory aids can be subdivided into two types of devices;(1)cuing devices that access internally stored information;(2) systems that record information externally.

Any device that acts as a cue for action, would be considered the first type of device. Harris (1978 p. 178) he suggests that for a cue to be maximally effective it should:

a. be given as close as possible before the time when the action is required. It may be no good reminding someone as they leave home in the morning to buy some milk on their way home from work.

b be active rather than passive. An active reminder would be an alarm watch with a note strapped to the back as opposed to a diary entry.

c. be a specific reminder for the particular action that is required. A ring on the wrong finger may only remind the person of something to be remembered but not what that something is.

The second type includes those whose functions is merely external storage of information, either because it may be more accurate or complete than internal storage or because internal storage mechanisms may be over loaded as in the case of jotting down intermediate results during mental calculations. A combination of the types of devices makes for the most effective memory aid as externally stored information is of no use if one forgets to use it.

Environmental memory aids use the structure and design of one's environment in aiding memory. This can be especially important for individuals with memory impairments. Environmental memory aids can be divided into three categories:

1. Personal environmental cues
2. Proximal environmental cues, including equipment in the immediate environment
3. Distal environmental cues

Personal environmental cues are a form of commonly used memory aids. This is done by introducing a novel change to aspects of one's attire/personal appearance, to remind one to do something. Examples include putting one's ring or watch on the wrong hand, putting a string around a finger, or tying a knot to the inside of a tie. This type of environmental clue overlaps closely with the definition of external mnemonic. A limitation of this aid is that one may become accustomed to them and thus end out ignoring them. They do not remember the use of the particular memory, just that something is to be remembered.

Proximal environment clues are considered to mean those that deal with the lay-out within a room, a vehicle, or the design of a machine. Well structured and well organized environmental stimuli reduce the probably of a memory lapse. A key hook is an example of such a proximal environmental cue. Of course, if one does not hang a key on the hook, the aid is quite useless.

For distal environmental cues Kapur refers to the macro design. This macro design includes homes, buildings, streets, and transportation networks. This also refers individuals in a clinical setting, where distinctive uniforms and name tags facilitate name recall. The use of clear markings is important in the design of such structures especially for the memory impaired.

Many of these external mnemonics are of more importance to the memory impaired but their use is common across the population. Their use in an educational setting is not always appropriate but can at times be beneficial.

In high school, students will refer to smart books. This reference is to the previous user who did well academically. Many of these smart books have underlined or highlighted material and notes in the margins. Some students will get these books in an attempt to improve their own grades. Contrary to this belief, a study of emphasizing techniques in college textbooks, Flower and Barker (1974) concluded that it is more effective for learners to be emphasizing their own material rather than using someone else's emphasized material.

In the minds of many, most forms of external mnemonic devices may only be of use in organizing material or making sure you get to a test on time but of little use once you get there. Contrary to popular belief, external mnemonic devices can be a very effective aid to learning. They are limited in use in many instances only by the imagination of the instructor. There are a number of examples where teachers have been able to incorporate external mnemonic devices into instruction which does not corrupt the integrity of the testing process. Strong (1986) has found that the electron configurations can be taught by a method which uses the periodic table as mnemonic device. This method may also be adapted to the prediction of quantum numbers.

Other uses of external mnemonics utilize objects at hand. Direction of torque may be determined by using a pencil laid on a sheet of paper. One hand is used to create the pivot point the other to simulate the force. There are times that the mnemonic at hand is the learners hands. Sears (1958), describes a method of determining the direction of three mutually perpendicular sets of vectors known as the left hand rule. In the left hand rule, the first finger points in the direction of the Field, the second finger in the direction of the velocity, or speed, and the thumb points in the direction of the Thrust. As you can see, this process also combines the use of first letter mnemonics. Similar to the left hand rule, a more commonly used external mnemonic in physics uses the figure to determine the direction of fields. In the biological sciences, hand models can be used to represent dynamic processes. Ward (1988), describes a demonstration using hand models to describe the processor mitosis. Biermann

(1989), uses hand models to illustrate guard cell activity and the sliding - filament theory of muscle contraction. These latter external mnemonic devices combine visualization techniques to enhance their effectiveness.

Since not all external mnemonic clues are presented on the test paper or readily at hand, other measures may be necessary. Some mnemonic devices may require the sketching of a diagram from which many other pieces of information may be derived. One such example of this is found in Rodriquez and Brainard (1989) article "An Improved Mnemonic Diagram for Thermodynamic Relationships". In this article the drawing of the axis labelled with the variables P,V,S,T,A,G,H, and U, is described as a means of developing a number of important expressions in thermodynamics.

Acronyms

Acronyms are widely used as a mnemonic encoding device. An acronym is a word made up of the first letters of several other words (Montgomery ,1979). Examples of these are very commonplace the United Nations Educational Scientific and Cultural Organization is commonly known as UNESCO. NATO is the acronym for the North Atlantic Treaty Organization. These shortened forms have come to replace many unwieldy names as they are much easier to handle.

In order to remember facts and formulas in science instruction, acronyms are commonly used. In (Postigliane, 1981 and Jackson and Anderson, 1985) the examples of the acronym Red Men Chris is given to mean the ten systems of the human body: The first letter in the Reproduction, Excretory, Digestive, Muscular, Endocrine, Nervous, Circulatory, Integumentary and Skeletal Systems, create the three word acronym. Some acronyms are created that are not single or series words representing the first letter but words in the form of a rememberable phrase. These phrases can represent both facts and formulas. The force of attraction of the Earth for another mass:

$$F = \frac{GM_{\oplus} M_{c}}{R^2}$$

may seem more memorable if read, "F = Gee, Mommie over separations between centres squared," (Fowlers ,1984). The relationship for displacement of an object:

$$S = Vot - \frac{1}{2} a t^2$$

can be remembered by *Science is Very Often Tremendous and Adventurous Half The Time* (Stewart ,1971). What might a student do if they had a number of formulas to remember as found in the following list:

1. $IMA = \frac{Hd}{Vd}$
2. $P = \frac{F \times Fd}{t}$
3. $P = \frac{W}{t}$
4. $IMA = \frac{Fa}{La}$
5. $Fff = \frac{AMA}{IMA}$
6. $AMA = \frac{L}{F}$
7. $W = F \times Fd$
8. $Eff = \frac{Wo}{Wi}$
9. $IMA = \frac{Fd}{Ld}$

One year my student created a list of phrases to help them remember the formulas.

1. I'm a hooked dude on vehicle doctoring.
2. Power fasteners fix devices on time.
3. Phone work on time.
4. Ice milk, a favourite appreciated over lemonade anytime.
5. Egos are mainly on over inflated male apparition.

6. All men are loading on fuel.

7. Walk fast from danger.

8. Emergencies would occur over work injuries.

9. Interns might administer fast doctoring on limb damage.

The following anagrams used the words "on" and "over" to represent the operation of division. This is in a way similar to how Folwer (1984) use "is" in order to represent an equal sign. This is similar to how a mathematical function might be represented in Yodai in mnemonic device: To further the effect of the anagrams they can be woven into a story as in Connolly (1993).

Story

Ring, Ring

Betty: Hello.

June: Hi Betty. This is June. Did you hear about Pat?

Betty: No.

June: Well, you know how he's always saying "I'm a hooked dude on vehicle doctoring."

Betty: Yes. What a laugh. I remember when he came over and fixed my clock. He said "Power fasteners fix devices on time." Of course the clock didn't work the next day and I did not phone work on time.

June: I remember he was arguing with your kids that "Ice milk, a favourite appreciated over lemonade anytime. But we are getting off the topic. At the morning break he was bragging to his boss about how fast they could load a truck with fuel barrels.

Betty: Well, of course. Egos are mainly an over inflated male apparition.

June: After break Pat yells "all men are loading on fuel." Well he had barely pulled away with the loaded truck. Some barrels fell off. Pat walked fast from danger but not fast enough.

Betty: What do you mean?

June: The fuel blew up. Luckily they knew emergencies would occur over work injuries and were prepared. Now Pat is in the hospital where interns might administer fast doctoring on limb damage.

Betty: Why didn't you tell me this earlier. I have got to go to the hospital and see if my brothers all right. Bye June.

June: Bye Betty.

The availability of acronyms is only limited by ones imagination. If you are having to get started, you might try looking at many of the available books on mnemonics. One book that provides an extensive list of mnemonic aid is a Dictionary of Mnemonics by Eyre Methuen Limited. The aids include topics in mathematics, biology, chemistry, and physics.

RHYMES

Rhymes are another commonly used mnemonic device people use without realizing it.The creation of rhymes is a process that can be adapted to many content areas. If you were asked how many days were in November, you might, like many people, use this common rhyme to remember:

> Thirty days hath September, April, June, and November. All the rest have thirty-one, and February has twenty-eight, except in a leap year, that's the time, that February has twenty-nine.

IMAGERY MNEMONIC TECHNIQUES

The most basic distinction between various internal mnemonic devices can be made between mnemonics that primarily involve organizing operations and those that involve encoding operations. The association in memory units of information that at first appear unrelated is considered an organization operation. An encoding operation transforms a unit of information into some other form so that it can be fit into some organizational scheme. This distinction corresponds with the unitizing and symbolizing processes in memory.

Both organizational and encoding mnemonics can be used in imagery mnemonic techniques.

Face-name Mnemonics

Face-name mnemonics combines both imagery techniques with an external cuing device. First, the user identifies a prominent facial feature, then transforms the to-be-remembered name into an image. This is followed by the superimposing of the image on the facial feature. Recall of the name requires using the facial feature as a cue for recall of the image, then transformation of the image back into the to-be-remembered name. Greenberg and Powers (1987).

Face-name mnemonics has proved to provide significantly improved recall when all three components of the method are utilized (McCarty,1980).McCarty's work was with subjects that wer- university students. Yesavage,Rose,and Bower(1983) and Gratzinger,Sheikh, Friedman,and Yesavage (1990) have found that the method has produced significant results with elderly population. This application is gaining favour as a memory aid for elderly populations (Greenberg and Power,1987)

Link System

Link system is a two step approach, appropriate for serial learning tasks. First a visual image is formed for each item on the list, then an association is made for each item on the list(Higbee 1976).

From the chain of associations in which a visual association is formed, between the first two items, then between the second item and the third, the link system took its name. Contrary to research by Lorayne (1974), which suggests that ridiculous imagery improved the memory, Higbee (1976) found this was not necessary to improve recall. What was important was that the images be vivid and involve interactions among the items being associated. For example, suppose you had to remember a list of five items found in the Canada's food guide.The list might include fish, potatoes, milk, tomatoes,and bread.

The first step would be to form a vivid image of the fish possibly swimming in an enormous hollowed out potato. The liquid in the potato is milk. Floating in the milk are a number of tomatoes which have slices of bread tied to their back as life preservers. These images form a chain of events which allow the user to visualize the items to be purchased.

The inclusion of an additional item to the list just required another association. One pitfall of this method is that like a chain, it is only as strong as its weakest link. Thus, the fact, that in the link system each item is associated with the previous item, creates the pitfall that forgetting one item, affects memory of subsequent items.

To increase the strength of the chain a variation of the Link System, known as the Link Story System, can be used. The Story System uses sentences as verbal mediators to form a story. The addition of another item to a list requires the use of additional sentences.Let us reexamine the previous list of five foods using sentences as mediators instead of paired associations:

> The fish and potato chips were very hot.
> The potato chips were so hot, that I washed them down with milk. Unfortunately the milk tipped over and spilled on the tomato ketchup. The Milky tomato ketchup then ran over the breaded fish.

For some people, the creation of a series of events makes the recall process easier. This, however, does slow down the association process because it may take longer to create a narrative. The larger the list of words, the harder it becomes to weave them into a story, Bugelski (1974), found that most people found it much harder to use the Story System on a list of 20 items, where the difference in the level of difficulty from 10 to 20 items is negotiable with the Link System.

The narrative nature of the Story System is more conducive to one way directional recall, compared to the Link System. Despite difficulties inherent in the Story System, it is the most commonly used mnemonic device by people not trained in mnemonics(Higbee,1976).

The link system has been found to significantly aid serial recall Mueller and Jablonski(1970),Wood(1967)and Bugelski(1974). A more recent study by Roediger(1980), found that the link system out performed rehearsal condition on serial recall test. The link story has also produced significant results in the learning of word list(Manning,1975 and Murray,1974). Reddy and Bellezza (1983) are in agreement with early results using story mnemonic condition which significantly out performed the elaboration condition on free recall tasks.In a review of literature comparing various mnemonic systems and their use Herrmann(1987) found the link story was the most effective system for free recall tasks.

Loci System

An alternative method, the Loci System, is not limited by the fact that each item is associated with the previous item. That a break in one of the links in the chain of memory can affect subsequent items was the weakness of the Link Method. Instead the Loci Method associates items with a previously memorized list of images which are in some natural or logical order. The main premise of this system is that memory for locations will aid memory for the events associated with those locations. This list of locations becomes a mental filing system, which is used over and over again for various lists of material. The locations selected should be very familiar. Commonly used locations are landmarks on the way to work or some other familiar destination. Another commonly used alternative is the rooms of one's own home. This latter example shows how the distance between items on the list is not as important as their distinctness. Now once again, let us consider our list of fish,potatoes,milk,tomatoes,and bread.

Here, a teacher, might try to tie the knowledge of the Canadian provinces and commodities produced by them, with the list of foods found in the Canada food guide. The pre-memorized list of locations are the provinces of Canada. Our recall of the objects on our list is facilitated by an imaginary journey across mainland Canada.

Our trip begins in Nova Scotia, where we see fish being loaded off of the boats. Heading west, into New Brunswick, we find field after field of potatoes. Driving on into Quebec, we see the many dairy farms with there large stainless steel containers full of milk . Leaving Quebec and heading into Ontario, we find tomatoes growing everywhere. Leaving Ontario, we head into Manitoba, where wheat for making bread stretches to the horizon.

Now mentally travelling through the locations, we use these paired associations, to recall our list of words in a serial order.

The serial nature of the recall in the Link and Loci Systems does present difficulty if the user wishes to access the 8th item in a list of 10 items. The interdependence of the items, to be recalled, does not facilitate this type of memory task. The locations used in the Loci System are not easily converted to numerical values.

A number of studies have provided direct evidence that

Loci System can significantly improve memory Bower(1973),and Groninger(1974).Watkins and Schadler(1980) and Kraft etal(1990) have found it an effective technique with very young children. Rose and Yesavage(1983),using both older and younger adults tested the effectiveness of the loci method with concrete and abstract nouns. Both experimental groups performed significantly better then control groups after instruction.

Peg System

A very similar system to the Loci System is the Peg System. The Peg System also uses a pre-memorized mental filing system to which items are attached. Where the Loci System has pre-memorized location, the Peg System has pre-memorized words known as peg words. The peg words are distinct concrete nouns as opposed to locations. Both these systems change free-recall tasks to a paired association task. These paired associations facilitate the direct retrieval of information unlike the Link Systems.

The Peg System provides concrete representation for numerical values in one of three ways. The first way, involves concrete objects which look like the digit they represent.

For example, the number one can be represented by a candle, two a swan, and three a trident and so on. Peg words can also be selected on the basis of meaning. For example: One - Me (there is only one me). Two-feet, three-pitch fork (three prongs) and so on Higbee (1976). These two previously discussed Peg Systems are not used nearly as much as the Rhyming Peg.

In the Rhyming Peg, the person develops a list of pre-memorized words that rhyme with numerical values. The following list could be used as a list for the numbers from one to ten:

One is the sun	Two is a ewe
Three is a tree	Four is a store
Five is a hive	Six is sticks
Seven is heaven	Eight is bait
Nine is wine	Ten is pen

To use this system, paired associations are created between the list of to-be-remembered items and pre-memorized list. Let us once again use our list of five foods.

First, we picture a fish being fried in the sun. Next a ewe is eating a potato. The following association would be a tree with cartons of milk for leaves. Tomatoes are remembered by visualizing them in a store. The fifth and final item on the list is remembered by visualizing a bee hive in the shape of a loaf of bread.

Higbee (1976), suggests that the major limitation of the Peg System tends to be the ability to find suitable peg words past ten. In his study of research, he could find only one study which had peg words to twenty and none going beyond twenty. A method which is similar to the Peg System in its production of paired associations is the Phonetic System.

Bugelski(1970) reported that people using the peg system recalled a list of ten words in order only after hearing it once. Those not using the peg system were likely to recall only half the list. Roediger(1980) and Reddy and Bellezza (1986) found subjects using the pegmethod performed significantly better on recall tasks.Wood and Pratt (1987) tested the use of pegword mnemonics with groups of adults age ranges 18-30,31-45,46-59,and 60-90.All four groups performed significantly better than control groups on recall tests.

Phonetic System

The Phonetic System is an encoding system which uses consonant sounds to represent numerical digits. This is accomplished with a series of information which is summarized in the following table (Higbee ,1976).

Digit	Consonant Sound	Memory Aid
1	t, d, th	"t" and "d" each have one downstroke
2	n	two downstrokes
3	m	three downstrokes
4	r	last sound for the word "four" in several languages
5	l	Roman numeral for "50" is "L"
6	j, sh, ch, soft "g'	reversed script "j" resembles "6"
7	k, g, hard "c", hard "g ", ng	"7" resembles a skeleton key "k" made of two 7's
8	f, v, ph	script "f" resembles "8"
9	b, p	both resemble "9" when inverted
0	z, s, soft "c"	"z" = "zero", "c" = "cipher"

The use of this, also involves the application of a few rules. The vowels, a,e,i,o,u, have no value whatsoever in the phonetic alphabet. Like the letters w,h, and y, they are disregarded. The only time "h" is important is when it follows certain consonants, changing the sounds (Lorayne and Lucas 1974). An example of the application of this rule wold be the word "throw". Throw has a value of 14. As you can see, in this word, the vowel "o" and constant "w" have no value.

The next rule involves the disregarding of silent letters. The work Know would transpose to 2 in the phonetic alphabet, Not 72. As this rule emphasizes ignoring silent letters, the "k" has no value. The word comb transposes to 73 not 739.

Difference in pronunciation does not cause any difficulty for the user as that person will constantly pronounce words with the same accent. Therefore, the person who pronounces that "b" on the end of the word comb will transpose the number 739, consistently for that user.

The next rule is simple and definite. Always consider double letters as making only one sound. The word matter transposes to 314, not 3114. An exception to this rule is a word like "accident" where it is obvious that both are pronounced. Here the double "c" is transposed to 30.

Finally, the letter "x" will almost never be used, but it transposes according to the way it is pronounced in a particular word. In the word fox, the "f" is 8 and the "x" is

70. The "x" makes the K's sound in the word Lorayne and Lucas (1974).

Having become familiar with the operation of the Phonetic System used in two general ways: (1) keywords may be constructed as a mental filing system; and (2) any numerical value can be coded into words. The first use closely parallels the use of the Loci and Peg Systems. The Phonetic System can construct a mental filing system, that can be used the same way as locations are used in the Loci System and the peg words are used in the Peg System.

Now using the Phonetic System, it is possible to create a list of peg words or key words for numbers beyond twenty, with no difficulty. Let us look how it is to generate from one to 70.

1	=	the	11	=	tide	21	=	net
2	=	knew	12	=	tone	22	=	nun
3	=	my	13	=	dome	23	=	name
4	=	were	14	=	dry	24	=	near
5	=	lie	15	=	tile	25	=	neel
6	=	jaw	16	=	dish	26	=	nich
7	=	key	17	=	tag	27	=	knowing
8	=	view	18	=	dive	28	=	knife
9	=	bee	19	=	top	29	=	nap
10	=	sea	20	=	dose	30	=	nose

Besides the advantage of being able to generate key words for numbers beyond 20, this method can produce a much larger choice of the words to create a Link Story.

In the following sentence you will see an example of four item list and numbered. This makes it easier to shorten the length of Link Stories making the memory task easier.The **fish** knew **bread** and my **apple** were **cheesy** bait. This sentence lists four items in the Canada's food guide.

The second function as means of encoding numbers are more often used as performing tricks as opposed to an educational tool. Lorayne and Lucas (1974), give the example of 91852719521639092112 which can be encode to the statement: "A Beautiful naked blond, jumps up and down". The statement is much easier to remember than the number. A more academic use of this system might be: "The viewing on Prince Edward Island is breathtaking." The words "The viewing on" transpose to 1872, the date Prince Edward Island entered confederation.

Little research has been done on encoding mnemonics compared to the amount of work done on organizational mnemonics (Bellezza,1981).Slak(1985) also notes little research has been conducted to test the phonetic system under laboratory conditions.Some early research by Slak(1970) found both phonetic methods tested produced significantly better in memory span for numerical digits. Ericson,Chase,and Fullon (1980) reported where a subject increased his memory span from 7 to 79 digits using a phonetic system.Patton and Lantzy(1987) found when subjects are thoroughly trained and have keywords representing numbers supplied to them,the phonetic mnemonic method facilitates the recall of numbers.Similarly Patton,O'Agaro, Gaudette(1991) found that experimenter generated mnemonics produced significantly better results on number recall then subjects in the control group.

Keyword Method

A encoding method dubbed the Keyword by Atkinson (1975), uses a phonetic encoding system. In his experiment, the Keyword method was used to divide foreign word learning into two stages. The first stage requires the subject to associate the spoken foreign word with the Keyword, an association that is formed quickly because of acoustic similarity. The second stage is comparable to a paired-associate procedure involving the learning of unrelated English words. Here the subject forms a mental image of the Keyword interacting with the English translation. An example of an application of this process is as follows. In Spanish, the word pato (pronounced something like "pot-o") means duck. Using the English word pot as the keyword, one could imagine a duck with a pot on its' head. Because of similar sounds in the word "pot" and "pote", an acoustic link is easily formed. When developing keywords, we need not always be a single word. For some items it may be a brief phrase if that phrase is particularly salient. This allows polysyllabic foreign words to be represented by the Keyword Method.

Since Atkinson's creation of the keyword method for foreign language learning, its use has been extended to other areas of instruction. Veit,Scruggs, and Mastropieri(1986) and Mastropieri,Scruggs,and Fluk (1990) found that students preformed significantly better than control groups learning unfamiliar vocabulary.

Mastropieri, Scruggs and Fluk (1988), use the Keyword Method in the teaching of abstract vocabulary to disabled students. The Keyword Method resulted in higher levels of recall and comprehension than a rehearsal condition. Their study also found that the Keyword Method was equally effective with both abstract and concrete vocabulary words.

Other studies by Desrochers,Gelinas,Wieland(1989) and Moore and Surber(1992) found the keyword method out performed control groups in the learning of German.

RECONSTRUCTIVE ELABORATIONS

The reconstructive elaboration model was developed by Margo A. Mastropieri and Thomas E. Scruggs during the 80's. The model consists of techniques for assisting students in remembering content area material by designing pictorial formats that are meaningful and familiar. By using the techniques of the model, unfamiliar content is made familiar and non meaningful information is made meaningful for learners. Research evidence suggests that when information is both familiar and meaningful to learners, it is more memorable. Underwood and Schulz (1960) report studies that have shown meaningfulness or familiarity strongly influences learning. Paivio (1971), reports that concreteness plays an important role in learning success. These works combined with the work of Rohwer, Rains, Eoff and Wagner (1977), that reported semantic elaboration of stimulus and response information facilitates associative recall, are the theoretical foundation of this model. Familiarity and meaningfulness of content in relationship to the target learners are bases of the development of the reconstructive elaborations. Scruggs and Mastropieri (1990), having done considerable research in this strategy with exceptional populations in both classroom and laboratory settings, found that it dramatically enhanced the classroom success of learning disabled and mildly mentally handicapped students.

The development of strategic pictures is influenced by both the "reconstructive" and elaborations" components. Reconstructive refers to the process used to modify material to more familiar form. Elaborations refers to the process of linking critical pieces together. Both components working simultaneously assist learners in more effective encoding of information Mastropieri and Scruggs (1989a).

Examples of the use of reconstructive elaboration to learn science content, are found in Scruggs and Mastropieri (1992). To teach that trichina is a roundworm found in uncooked pork and that the worm causes illness in humans, the keyword "trick" was employed to depict trichina. Since "trick" is not entirely concrete, a verbal elaboration was presented of trichina springing from a pig and saying, "I have a trick... I'll make you sick".

Numerous examples of reconstructive elaboration adapted to other content areas are found in (Mastropieri and Scruggs 1989a, Scruggs and Mastropieri 1990 and Mastropieri and Scruggs, 1989b). This versatility allows this mnemonic system to be incorporated across the curriculum.

Process Mnemonics

As an example of process mnemonics Yodai is an all encompassing approach to mnemonic instruction which incorporates words, sentences, rhymes, metaphors, etc.(Levin ,1985). Yodai was developed by a Japanese educator Mosachikd Nakane. Nakane believed that everything is based on rules. The secret to success is to learn the basic underlying rules or theory (Higbee ,1985).

How does this differ from other mnemonic devices we have examined? Yodai Mnemonics are directed at the acquisition of "procedural knowledge," whereas virtually all other empirically investigated mnemonic techniques have focused on the acquisition of "declarative knowledge "(Levin ,1985). Declarative-knowledge mnemonics are designed to facilitate learning such as the fact that Nova Scotia is one of the Atlantic provinces or that Prince Edward Island joined confederation in 1872. In contrast, procedural knowledge mnemonics are designed to facilitate the acquisition of skill sequences and processes, such as how to multiply and divide fractions, how to diagram chemical compounds, how to perform various trigonometric functions, or how to find the main idea in a reading passage (Levin ,1985).

Higbee and Kunihira (1985) describe the following three categories of Yodai mnemonics:

1. formulas and numerals
2. definitions, principles, and concepts
3. process of solving problems

Nakane contended that it is not necessary to introduce children to the entirely new and abstract language of mathematics. Instead mathematical processes are described in terms of concrete and familiar objects. Kilpatrick (1985) considers the extensive use of language in Yodai mnemonics as possibly a major advantage for American children.

There are those detractors of Yodai that feel that the system is not culturally relevant to the American learning situations. It is true that many of the mnemonics developed in Japan do not translate well into English. But it does not preclude the development of new mnemonic devices. Kilpatrick (1985), claimed that Yodai will promote doing before understanding. Levin (1985) believes that by targeting procedural knowledge, process mnemonics offers the following innovative educational possibilities:

1. That process mnemonics may be a key to unlocking the door to a student's efficient independent learning.
2. That these mnemonics strategies are applicable to a variety of complex skill domains.
3. That the Yodai mnemonic system does promote comprehension well beyond that learned in rote learning situations.

Nakane's mnemonics are intended to serve as retrievable mediators for learning and recalling the orderly cognitive processes required in problem-solving. Symbols and words found in the problem to be solved are used as cues for solving it. Students recognize the process for the solution through cues in the problem to be solved. Less elaborate process mnemonic systems are found in American curriculum. The Foil method for multiplying two binomials is an example: (a + b) (c + d)

First terms ac

Outer terms	ad
Inner terms	bc
Last terms	bd

Yodai mnemonics, on the other hand, is much more vivid. The same mathematical problem of multiplying binomials is expressed in terms of wrestling. Each term in parenthesis being a wrestler of either the east team or the west team. Each wrestler on the west team wrestles each wrestler on the east team, so that (a + b) (c + d) = ac + ad + bc + bd. Higbee and Kunihira (1985). This more vivid approach has not been fully researched as to its improved performance over other mnemonic devices. As Yodai mnemonics uses a number of mediators, both visual and oral, it has as of yet not been determined which are the most effective. Yodai mnemonic is a relatively untested area of educational research. Higbee and Kunihira (1985) cite the performance of Nakane's graduates as evidence of its successfulness. A high percentage has gone into various professions such as medicine and engineering.

A concern expressed by both Pressley(1985) and Levin(1985) is the lack of controlled research data bearing on Yodai and its underlining components.They both make reference to a study by Machida and Carlson(1984) as the one research study which does provide empirical evidence of the benefits of Yodai.Machida and Carson found significant differences favouring the experimental subjects on both immediate post-test and the 2-week delayed post-test.

Reviewing the various internal mnemonic devices it becomes apparent that the use of imagery is a common thread that runs through virtually all mnemonic aids. The use of visual imagery is also by far the most thoroughly researched mnemonic techniques.

References to imagery date back to Aristotle, whose formulations correspond quite closely to the position taken today by many cognitive psychologists. In Memoria he writes:

> "We cannot think without imagery, for the same thing occurs in thinking as is found in the construction of geometrical figures. There though we do not employ as a supplementary requirement of our proof a determinateness in the size of the triangle, yet when we draw it we make it of a determinate size. Similarly in thinking also, though we do not think of the size, yet we present the

object visually to ourselves as a quantum, though we do not think of its quantum." (quoted in Wetherick, 1991, p. 255)

Aristotle like most of us experienced visual imagery while thinking. Imagery is a large component of many mnemonic devices. Why are mnemonic systems not more popular?

Could it be that our modern attitude towards mnemonic devices has been shaped by attitudes from the Renaissance era? Although the study of mnemonic devices was an essential part of rhetoric, the during classical era many of the great mnemononists of that time were followers of Hermes Trismegistus, who reputedly lived in Egypt at the time of Moses (Bellezza,1981). Thus, classical art usually regarded as purely mnemonotechnical, had a long history in the middle ages and was recommended by Albertas Magnus and Thomas Aquinas. In the Renaissance, it became fashionable among the Neoplatonists and Hermetists. The latter group, by reflecting on the universe in the mind, is thought to be the root of Renaissance magic memory. By using magical images as memory images, the user was thought to be tuned into the powers of the cosmos. Because of these practices, the Hermetic philosophers gradually lost influence, with extremists such as Giardano Bruno ending up as victims of the inquisition (Yates,1964).

Hostility toward Visual imagery increased as a response to Hermetic magic of which imagery was an integral component. Yates (1966) characterized negative reaction toward Visual imagery as an "inner iconoclasm" which accompanied the movement against graven images and religious art in general during the time of the Reformation. This association of magic and visual imagery seems to have carried over into our own time. This is exemplified by the recent banning of a number of children's books in British Columbia schools which contained images that were thought to be linked to the supernatural.

The study of visual imagery, though not always mnemonic devices, has managed to remain an important topic in academic studies throughout the centuries despite of the adversities it has faced. In the early twentieth century, it was banished from psychology until its relatively recent reappearance (Bellezza ,1981).

It is evident that formal mnemonic devices do not have history on their side. So why this renewed interest in them in the age of information technology? Information is no longer passed down from generation to generation by word of mouth. One has a variety of methods at one's disposal to disseminate information ranging form paper to electronic recording devices. Now that we have access to large amounts of information via personal computer technology, many ask why do we have to remember if we know how to access this information. Another reason mnemonics are not being used commonly in today's society is that to be effective many mnemonic devices require a great deal of effort for the user.

MNEMONIC IMAGERY IN INSTRUCTION

As a teacher, one often ponders the question, "How can I get my students to learn more"? A difficult question to answer at the best of times, and even more so if one must add to the learning equation the varied group of learners one might find in an adult basic education class. In these classes, students ranging in age from 18 to 60 must come together to create a meaningful learning environment for all. Teaching techniques involving the use of imagery have a role to play in such an environment. The use of imagery has long been considered superior to words in promoting learning, especially since pictures evoke imagery at all age levels. Imagery has also been suggested as a method to improve memory in older adult learners who are increasingly participating in learning situations (Greenberg and Powers, 1987). Thus, it seems quite plausible that the use of imagery techniques might enhance the instruction of adult basic education students. In considering the plausibility of visual imagery to improve learning one must examine the types of learning situations for which imagery has proven beneficial.

The use of visual imagery as a method of facilitating recall has been demonstrated in a series of verbal/pictorial paired-associate studies (Rasco ,1975). Davidson (1964) found that picture-invoked imagery produced significant effects in paired association tasks. Marks (1973) found that the reported vividness of the subject's imagery of pictorial data facilitated accurate recall.

Rasco's (1975) reports, that imagery is superior to words in promoting learning at all age levels, have special implications for older adult learners. Learners over 55 years of age are an increasing population participating in formal learning situations. Memory performance is essential to successful learning, yet memory exhibits a significant age related decline. Imagery has been examined as one of a variety of interventions found to improve memory function for older adults (Greenberg and Powers, 1987).

The use of pictorials as a facilitating aid to recall, either by evoking images or by associating paired objects has resulted in subjects regularly outperforming those left to their own strategies (Rasco ,1975). Also, learners directed to create mental images of the events described in sentences learned two to three times as much as learners who repeatedly read the sentences aloud (Anderson ,1971). Anderson and Hidde (1971) found that subjects instructed to form images of the events described in sentences recalled more than three times as many words on a surprise test as people who pronounced the sentences. Anderson argues that imagery instruction facilitated learning by causing subjects to process the sentences in a meaningful fashion. Anderson and Kulhavy (1972) found that high school seniors who reported using imagery to remember prose significantly out performed those who did not.

Similarly, investigation of the effect of instruction directing the learner to form mental images of the prose materials and relevant drawings on task,thereby requiring the processing of verbal information rather than direct recall, has demonstrated the superior performance of these strategies (Rasco ,1975). Les Gold,McCormick,and Galinkoff (1975) found that fourth grade children could improve their prose learning ability through cartoon training to illustrate prose passages which was accompanied by explicit imagery instruction.

In a similar vein Pressley (1976), conducting a study over a four week period with eight year old subjects, investigated the benefits of using mental imagery to remember phrases. Subjects received practice constructing mental images of progressively longer prose passages. Passages progressed from sentences, to paragraphs, and finally short stories. Experimental subjects answered significantly more short answered questions about the short stories than controls did. Rose, Cundick, and Higbee (1983), in an investigation to determine the effects of verbal rehearsal, visual imagery, and unaided instruction, found that the visual imagery condition significantly out performed students in the unaided instruction conditions.In this study, children in the visual imagery condition were instructed to pause after reading a few sentences, close their eyes, and "make pictures or a movie" in their mind about what they had read. The results support the author's contention that learning-disabled children can benefit greatly from cost-effective mnemonic training procedures which increase the number of learning strategies available to these students. This finding concurred with results reported by Pressley (1976) which found that nine learning disabled children, when instructed on imagery techniques, performed significantly better in the experimental than those in the control groups.

Atkinson, (1975) conducted experiments using a vocabulary of 120 Russian words displayed on a CRT as part of a computer assisted learning program. The subjects, Stanford University students, were tested for immediate and six week delayed comprehension of the vocabulary items. Recall using the keyword method approached double that of the control group on both immediate and delayed comprehensive tests. This yielded results that were highly statistically significant in favour of the keyword method. This work has been replicated and modified to produce positive results in various areas across the curriculum including the areas of science instruction. Mastropieri, Scruggs and Levin (1985) in a review of the use of mnemonic techniques found the keyword method consistently out performed other techniques with exceptional students. This study also reviewed the positive influence of combining the keyword method with other mnemonic devices in the study of geological science. Mastropieri, Scruggs and Fulk (1990) conducted a study with a group of learning disabled students using the keyword method to answer a number of issues about its effectiveness. First, could the keyword method be used to teach abstract as well as concrete information? A second issue concerned the level of comprehension induced in students with learning disabilities taught via the keyword method. The mnemonic keyword instruction resulted in higher levels of recall and comprehension than a rehearsal condition. A lack of obtained item type by condition interaction suggests that the keyword method was equally effective, as compared with a rehearsal condition, for both abstract and concrete vocabulary words.

Mnemonic Imagery in Science Instruction:

A renewed interest in the theoretical aspects of mnemonics has in part inspired the use of mnemonic imagery in some class room practices. Popular literature for teachers has a wide variety of references to mnemonic techniques for aiding in the instruction of science materials. Many of these mnemonic devices are visual in nature. They can be as simple as the creation of a "tens triangle" to help students learn the number combinations that sum to 10 Greene (1985). On the other side of the spectrum they can be used to solve genetic problems (Postiglione, 1981), to give an outer electron configuration for any element (Strong, 1986), and even develop complex thermodynamic relationships such as the Maxwell Relations'(Rodriquez, 1989). Despite claims of increased student comprehension and retention, these claims are for the most part, based on intuitive beliefs rather than sound research.

One must look to more research oriented studies to answer the question: what is the role of imagery in science instruction? Study of this role was inspired by earlier work with imagery on paired association, sentence information retrieval, prose learning and second language learning. Interest has also been generated from studies designed to investigate the effects of imagery-inducing media and models which are believed to stimulate imagery. Works by Dwyer (1972) and Holliday (1975) support the notion that transfer tasks can be facilitated by the utilization of imagery related media. The studies demonstrate certain types of pictures or illustrations can significantly facilitate verbal comprehension.

The resulting research has touched many areas of the science curriculum. Scruggs, Mastropieri, Levin and Goffrey (1985) compared the memory of science facts in learning disabled students using mnemonic imagery with those receiving direct instruction and free study. The study found that the mnemonic instruction of the hardness level, colour, and use of ten minerals produced at least a two-to-one improvement in correct responses. A combination of the keyword method and the pegword method was used in this report.

Another study by Mastropieri, Scruggs, and Levin (1986) of a pictorial mnemonic technique in the learning of hardness levels of minerals has proved successful in a classroom application. In this study, the effects of direct and mnemonic instruction are compared in two experiments with exceptional learners. The results of the investigation make it clear that both LD and EMR students can benefit from a combined pictorial mnemonic strategy. The difference between amounts recalled under the two conditions for both groups was statistically significant.

Similarly, the use of mnemonics keyword and pegword techniques proved successful in a classroom setting (Veit, Mastropieri, and Scruggs 1986). The science content area involved was the names and attributes of dinosaurs and problems involving reasoning. Despite concerns to the contrary, it was found that the effectiveness of mnemonic systems did not diminish when presented over several days. Students receiving mnemonic instruction scored statistically higher than direct questioning conditioned students on all immediate and delayed recall tests, except the vocabulary test. That the difference favouring mnemonic instruction on the vocabulary lesson fell somewhat short of the required significance level may be a function of the fact that students were exposed to the materials for shorter periods of time than in previous investigations.

Levin,Morrison and McGivern(1986) found that mnemonic strategies can be effectively adapted to the task of remembering prose-embedded facts associated with scientific classification systems. This study was conducted with non learning disabled grade eight students. The mnemonic condition obtai[illegible] better results at statistically significant levels on immediate and delayed recall apposed to both figural taxonomy and free study conditions. In addition, when questioned on the helpfulness of the method used, mnemonic subjects gave mean helpfulness ratings that were statistically higher than those associated with either summary of free-study.

Konopak and Williams (1988) did not have as positive results in a similar study with mnemonic images as only one of the groups tested had significantly better results. It was found that the below average students did not perform better as they did not utilize the key-word mnemonic instruction in the recall expository text material. In a similar study with learning disabled students, Konopak, Williams, and Jampole (1991) had inconclusive results with a case study of learning disabled junior high students. In both of these studies (1988,1991) the duration was four class periods which did not seem to provide enough time for two of the three groups involved to master the techniques. This assumption would seem to be supported by a similar study by Morrison and Levin (1989) in which below average reading ability grade eight students used the key-word method with mnemonic illustration. It found that only students provided with instructor created mnemonics performed statistically better than other students.

Imagery and Problem Solving

The use of visual imagery in mathematical problem solving is not a new concept. The history of science is replete with instances of the employment of visual imagery in the solution of problems. Unfortunately, attempts to facilitate the use of imagery have usually been confined to fairly narrow contexts. Although psychologists have talked about training to improve imagery ability and as a means of improving problem solving ever since 1883,there is little evidence of progress at either the theoretical or pedagogical level Clements(1981).

More recent works have tried to answer the question:"Why does mental visualization facilitate problem-solving? " This question is also the title of an article by Alessandra Antonietti. In a series of four experiments, Antonietti (1991) found that his results supported the notion that visual images allowed subjects to avoid some of the main obstacles to productive thinking by transforming problem-situations in unusual but effective ways. In tasks whose solutions required simultaneous consideration of various elements, pictorials produced a high degree of success. Pictorials also aided subjects in forming visual representations which could partially overcome the tendency toward mechanization of problem-solving. Other authors have found that the use of visual imagery can produce positive results in problem-solving activities. Durndell and Wetherick (1976) found positive correlations between self rated use of imagery and performance of divergent thinking tasks. Kaufmann (1985) describes imagery as the most important function in the initial phase of problem-solving process. Simultaneous consideration of the whole problem field is facilitated by mental imagery, thus reducing the tendency to examine the single elements. Kabanova-Meller (1971) describes image in problem-solving as playing a positive role through subjects creating flexible a representation which permits unusual manipulations of problem elements. Martel (1990) describes this flexibility as important in eliminating uniformist thinking represented by such dogmas as "if it ain't broke, don't fix it" and that the best way of doing things is "my way" attitude. Imagery studies were conducted by Fullerton(1983) on age differences in the use of imagery in integrating new and old information in memory. The results suggest that for younger adults imagery used as a control process is a factor that encourages both inferencing and integration of previous knowledge with new information. In older students the results suggest that they are able to use imagery as a control process when it is combined with a contactual framework. The age range of the younger groups was from 20 to 39 where the older group ranged in age from 60 to 80. This study unfortunately does not provide further insight into the use of imagery with adults ranging from 40 to 59, an age range often found in adult basic education class. The age where imagery is going to have a varying effect can only be surmised at this point, thus changes in instructional style would be on a best guess basis.

Kaufmann (1979), in a study involving 44 secondary students found evidence to support the hypothesis that pictorial analogies may be part of the mediation process in problem-solving. These conclusions were based on results showing that the ability to solve a problem is closely related to the ease of finding a pictorial analogy for its solution. In another study, titled "Visual Imagery and Problem-Solving", Kaufmann (1985) reports visual presentation will facilitate problem-solving performance. It is argued that the presentation of pictorials does not constitute an advantage due to difference in information as both groups had no difficulty in grasping concepts involved in the problem.

In the studies we have discussed, mnemonic imagery devices were shown to produce positive benefits in the learning of science facts. In a number of studies it has also been found that higher level learning could be promoted using mental imagery. In these studies the positive effects of imagery utilization on problem solving were ascertained. One of these studies by Gabel and Sherwood (1983) involved the instruction of problem solving in chemistry, while others involved concepts in physics and biology.

Gabel and Sherwood (1983) studied whether certain types of instructional strategies were superior to others in teaching high school students problem solving in four topics integral to every chemistry course. These topics were the mole concept, the gas laws, stoichiometry, and molarity. Data was obtained from 421 students over one school year. Students were randomly assigned to four instructional strategies used within each classroom. Two of the four instructional strategies the teachers used, analogies and diagrams, were considered to be related to the memory structure "images"; whereas two others, the factor-label method and proportionality, were more directly related to the memory structure "intellectual skills". Findings from this research indicated that the diagram method was superior and the factor-label method inferior for students showing high mathematics anxiety and low visual preference on the immediate post-tests for the four chemistry units. Results were statistically significant or tending in that direction. For students having high mathematics anxiety and low proportional reasoning ability, the analogy method, the other imagery strategy, proved best at significant levels. McIntosh (1986) designed a study to investigate the effect of teacher-induced imagery generation on rule recall and transfer. This study uses instructional strategy closely related to (Gable and Sherwood ,1983). The subjects were ninth grade physical science students learning Boyles' Law. The results of the study indicate that imagery utilization significantly facilitates rule recall, a finding similar to that of (Paivo,1971). It was also found that the imagery encouragement during instruction leads to significant rule transfer gains for low imagery students.

Problem-solving, although most often thought of as the application of learned rules, can refer to a wide range of intellectual activities. In a botany course, problem-solving ability might measure students proficiency to determine which order a given "mystery" specimen could be based on when only one or two of the three characteristics needed to specify an order was available. Levin, Rosenheck and Levin (1988) hypothesized that a dual mnemonic approach would be more useful than the usual figural taxonomy approach in allowing college students to acquire both high-order structural and low-order detailed information when learning botany concepts.

Students receiving the two-component mnemonic treatment performed significantly better than those receiving the other treatment, thus supporting the authors' hypothesis. Two important conclusions emerge from the experiments on the use of mnemonic science instruction. First, mnemonic strategies can be successfully extended to learning tasks that require an understanding of taxonomic relationships without sacrificing local, lower level details. A second important outcome of this research is that the two-component mnemonic strategy has produced durable benefits on both factual memory and the problem-solving tasks. These results are in agreement with Higbee's (1978) earlier defence of mnemonics and his claim regarding its "pseudo-limitations". Studies concerning the positive effect of imageries on problem solving are closely related to the purpose of this present study.

AN EXPERIMENT IN IMAGERY MNEMONICS

This study will investigate the effect of imagery encouragement and actual imagery utilization on a rule recall and transfer task. The former variable was arranged to determine if students who were encouraged to create a mental image of a specific concrete object, that is a component concept of a rule, will perform significantly better than those not encouraged to do so on a criterion test measuring rule recall and transfer. Additionally, it is of interest to determine whether students who reported using a high degree of imagery would perform significantly better on the criterion test than students not reporting high imagery use. The mnemonic instructional strategy will be applied to nine physics formulas used in the calculating of mechanical advantage ,efficiency, work,and power.The study will use a mnemonics process mode of visual anagrams in the investigation of the effects of imagery on the recall and the application of science formulas.

METHOD:

Subjects:

The subjects were 40 students enrolled in one of four intact science classes at a community college. The science classes are part of an academic upgrading program which makes available to adult learners the academic prerequisites needed for entry into many occupational courses. The subjects are enrolled in a level III upgrading. In general, the Level III upgrading program approximates public school grades nine and ten in the subject areas of mathematics, science and communications. The group being delivered the imagery encouragement treatment was composed of twenty subjects, ten females and ten males. The imagery discouragement group was composed of twenty subjects, six female and fourteen male students. The two groups were tested for mathematical skill and reading ability before entry into the program. The mathematical skills test was an in house exam developed by the community college system based on the requirement of the level 2 upgrading program. The reading comprehension test was part of the Canadian Adult Achievement Test developed for Canada Employment and Immigration Commission by the Psychological Corporation. Results of the mathematics testing found that the experimental group averaged 66.6 % with a standard deviation of 11.34% the control group averaged 75.78% with a standard deviation of 15.07% .The results of a One Factor ANOVA were not statistically significant with a $F = 2.282$ and a $p = .1492$. The results of the reading comprehension testing found that the experimental group average grade level was 10.32 with a standard deviation of 2.22 grade levels; the control group averaged grade level was 9.86 with a standard deviation of 2.11 grade levels .The results of a One Factor ANOVA were not statistically significant with a $F = .215$ and a $p = .6487$.

Materials for the investigation included the textbook Modern Physical Science and specifically developed materials based on the textbook. Content covered came from section 16.1 (machines) of chapter 16 "Using Force and Motion". For both sets of materials (mnemonic and traditional), overhead transparencies and student hand-outs were included. For the mnemonic condition, pictures were developed to represent applications of nine formulas, a strategy largely based on the theoretical foundations of the reconstructive elaboration model(Mastropieri & Scruggs ,1989b).

Symbolic reconstructions were employed, in which symbolized pictorial representations were shown interacting with relevant target information. Functions are indicated by verbal mediators which are prepositions of location. For example, to teach that **Power = work / time** a representative picture was constructed of a person standing on an alarm clock phoning work which is Nova Scotia Power. The caption reads "phone work on time". The formulas were copied on transparencies for use with overhead projectors. In addition, the experimenter provided information on the target content, as well as mnemonic retrieval information. The groups were instructed in an expository mode using either the image-encouragement or the image discouragement mode. Instruction and testing occurred over a period of seven fifty-minute instructional periods. Students were given a pretest prior to instruction and a post-test following instruction. Students also were requested to complete an introspective questionnaire designed to determine if the students utilized imagery techniques while answering the test items.

With the exception that no mnemonic strategy information was provided, materials in the traditional instruction condition paralleled those in the mnemonic condition. For example, the overhead transparencies consisted of target information only, without reference to mnemonic elaboration. Teacher instruction was the same as those in the mnemonic condition, with strategy information deleted. Student worksheets were taken from the published materials and included traditional practice activities on the target information, such as matching and problem-solving sheets.

Procedure:

The study was carried out over seven instructional periods of 55 minutes in the regular classroom setting for both groups. Instruction was provided to both groups by the researcher.

DAY 1 :

Class 1 - During the first class the students were told that the experiment was to test two types of instructional methods. This was done in a manner that did not allude to any benefits of one method over an other. Following this explanation, students were tested on knowledge of formulas (pretest1) and problem-solving ability (pretest2) on one step problem solving.

Next students were introduced to the material in the unit. As each of the formula was encountered, it was handled in one of two ways. The mnemonic imagery condition was presented with a pictorial mnemonic device on the overhead with copies for each student. The students were asked to form a mental image of the picture. In forming that picture, the students were reminded of the imagery which had been used to describe the equation and its application. Students in the control group copied the formula and its application from a list presented on the overhead projector. These formulas were then reviewed using verbal rehearsal techniques.

Class 2 - Students reviewed the work covered in the previous class. The control group was prompted to recite previously discussed formulas which were written on an overhead transparency. The experimental group was read a story which linked the formulas into a brief story to facilitate recall. Students were again shown relevant transparencies as the story was read. After a brief review, both groups were given a work-sheet. The work-sheet was corrected and then both groups were exposed to problem examples. This occurred for the remainder of the class. Students in both groups were given a assignment sheet to complete for the next day.

DAY 2 :

Class 3 - Students were quickly shown the overheads from the previous classes and reminded of the purpose of the lessons: to learn the formulas, their application, and use them in problem-solving situations. The remainder of the class was spent correcting homework assignments and answering any questions on the material. Students were assigned work for study class. Students in the experimental group were reminded to use imagery when solving the problems.

Class 4 - Students were once again quickly shown the overheads from previous lessons. The students were reminded that the purpose of these lessons were to learn the formulas, their application, and use in problem-solving situations. This was followed by correcting the assignment via the overhead transparencies. The remainder of the class was spent on class problem-solving activities.

DAY 3:

Class 5 - Students were given two post-tests. Post-test 1 was on the recall of the formulas. Post-test 2 was on one step problem solving. In post-test-two students were given abbreviated versions of the formulas in order to facilitate the problem-solving process. A quick glance at the initial few tests made it obvious that the test instrument was not difficult enough to detect any variation in problem-solving ability. At this point it became obvious that additional testing would be required. Upon completion of correction of the tests during the noon break, it was found that both the classes had performed extremely well with little variation.

Class 6 - This class began with the administration of the Marks 'Vividness of visual imagery questionnaire' (Marks ,1973). The Marks questionnaire, used by MacIntosh (1986), was designed to assess a student's ability to form and to a limited extent manipulate visual images. A median split of each students composite imagery scores can serve to categorize students into either high or low imagery.After the questionnaire was complete, fifteen minutes into the class, the remainder of the class time was spent going over the post test from the morning.

DAY 4:

Class 7 - Students began with a second test on recall of formulas (post-test 3). This test was a matching as opposed to direct recall. This was followed by a second post which involved more complex multiple step problems (post-test 4).

As an experiment with students some difficulties did arise. All the students in the four groups had not been required to learn formulas previously in their science instruction. This resulted in some students not participating with a level of enthusiasm or cooperation that they might have normally displayed. The extensive testing procedure over such limited time span produced a high level of anxiety in a number of the students. On the other hand, this experiment for some students was an enjoyable way to be introduced to what are normally intimidating concepts to them.

RESULTS

EXPERIMENTAL VS CONTROL:

Pretests:

At the beginning of the experiment both groups were given pretests for formula knowledge (pre-test 1) and for problem solving (pre-test 2). The results of a one factor ANOVA showed no statistically significant difference between groups for results of pretest 1 ($F=2.064, p>.05$) and pretest 2 ($F=.831, p>.05$). See table 1 & 2.

One Factor ANOVA X_1: Group Y_1: Pretest1

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	1.225	1.225	2.064
Within groups	38	22.55	.593	p = .159
Total	39	23.775		

Model II estimate of between component variance = .032

One Factor ANOVA X_1: Group Y_1: Pretest1

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
A	20	.35	1.089	.244
B	20	0	0	0

One Factor ANOVA X_1: Group Y_1: Pretest1

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
A vs. B	.35	.493	2.064	1.437

Table 1

One Factor ANOVA X_1: Group Y_1: Pretest2

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	1.406	1.406	.831
Within groups	38	64.287	1.692	p = .3677
Total	39	65.694		

Model II estimate of between component variance = -.014

One Factor ANOVA X_1: Group Y_1: Pretest2

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
A	20	1.225	1.491	.333
B	20	.85	1.077	.241

One Factor ANOVA X_1: Group Y_1: Pretest2

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
A vs. B	.375	.833	.831	.912

Table 2

Pretest 1 - post-test 1

A repeated measures analysis of variance was conducted with pretest 1 and post-test 1 scores comparing the experimental group with the control group. The results of which are shown in table 3.

Results show the continued significance of effect for the repeated measure between pre-test 1 and post-test 1 with $F(1,40)=$, $p<.0001$. The interaction effect between experimental/control and pretest 1/post-test 1 was approached significance at $F(1,40)=3.564, p=.0667$.

Anova table for a 2-factor repeated measures Anova.

Source:	df:	Sum of Squares:	Mean Square:	F-test:	P value:
Group (A)	1	20	20	4.606	.0383
subjects w. groups	38	165	4.342		
Repeated Measure (B)	1	140.45	140.45	59.235	.0001
AB	1	8.45	8.45	3.564	.0667
B x subjects w. groups	38	90.1	2.371		

There were no missing cells found.

The AB Incidence table

Repeated Measure:		Pretest1	Test1	Totals:
Group	A	20	20	40
		.35	3.65	2
	B	20	20	40
		0	2	1
Totals:		40	40	80
		.175	2.825	1.5

Table 3

Combined Tests:

At the beginning of the experiment both groups were given pretests for formula knowledge(pretest 1) and for problem solving (pretest 2) these scores were combined to create a combined pretest score. The results of a one factor ANOVA showed no statistically significant difference between groups for results of combined pretests ($F=2.191, p>.05$).See table 4.

One Factor ANOVA X_1: Group Y_1: pretests

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	7.656	7.656	2.191
Within groups	38	132.788	3.494	p = .1471
Total	39	140.444		

Model II estimate of between component variance = .208

One Factor ANOVA X_1: Group Y_1: pretests

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
A	20	1.725	2.414	.54
B	20	.85	1.077	.241

One Factor ANOVA X_1: Group Y_1: pretests

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
A vs. B	.875	1.197	2.191	1.48

Table 4

Combined Pretests - Combined post-tests

A repeated measures analysis of variance was conducted with combined pretest and combined post-tests scores comparing the experimental group with the control group. The results of which are shown in table 5.

Means on the pretest for the experimental group were higher than the control group. There was no significant difference between experimental group and the control group before treatment since $F(1,40)=2.191, p=.1471$ (Table 4). Results show the continued significance of effect for the repeated measure between combined pretests and combined post-tests with $F(1,40)=229.751$, $p<.0001$. The interaction effect between experimental/control and combined pretests/combined post-test was significant at $F(1,40)=4.446, p=.0416$.

Anova table for a 2-factor repeated measures Anova.

Source:	df:	Sum of Squares:	Mean Square:	F-test:	P value:
Group (A)	1	175.824	175.824	5.2	.0283
subjects w. groups	38	1284.916	33.814		
Repeated Measure (B)	1	4515.013	4515.013	229.751	.0001
AB	1	87.362	87.362	4.446	.0416
B x subjects w. groups	38	746.766	19.652		

There were no missing cells found.

The AB Incidence table

Repeated Measure:		pretests	posttests	Totals:
Group	A	20 1.725	20 18.84	40 10.282
	B	20 .85	20 13.785	40 7.318
Totals:		40 1.288	40 16.312	80 8.8

Table 5

Formula Recognition and Multi-step Problems

As there was no pretests for formula recognition(post-test 3) or for multi-step problem solving (post-test 4) a one factor ANOVA was used. The results showed statistically significant difference between groups for results of test 3 ($F=7.114, p=.0112$) and test 4 ($F=2.102, p=.0071$). See table 6 and table 7.

One Factor ANOVA X_1: Group Y_1: Test3

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	50.625	50.625	7.116
Within groups	38	270.35	7.114	p = .0112
Total	39	320.975		

Model II estimate of between component variance = 2.176

One Factor ANOVA X_1: Group Y_1: Test3

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
A	20	5.9	2.269	.507
B	20	3.65	3.014	.674

One Factor ANOVA X_1: Group Y_1: Test3

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
A vs. B	2.25	1.708*	7.116*	2.668

* Significant at 95%

Table 6

One Factor ANOVA X_1: Group Y_1: Test4

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	17.03	17.03	8.1
Within groups	38	79.893	2.102	p = .0071
Total	39	96.924		

Model II estimate of between component variance = .746

One Factor ANOVA X_1: Group Y_1: Test4

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
A	20	2.04	1.816	.406
B	20	.735	.953	.213

One Factor ANOVA X_1: Group Y_1: Te.t4

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
A vs. B	1.305	.928*	8.1*	2.846

* Significant at 95%

Table 7

IMAGERY UTILIZATION VS NON-IMAGERY UTILIZATION

Pretests:

The tests given at the beginning of the experiment to both groups were examined to test for differences between imagery utilization and non-imagery utilization. The results of a one factor ANOVA showed no statistically significant difference between groups for results of pre-test 1 ($F=2.064, p>.05$) and pre-test 2 ($F=.831, p>.05$).See table 8 & 9.

Anova table for a 2-factor repeated measures Anova.

Source:	df:	Sum of Squares:	Mean Square:	F-test:	P value:
utilization (A)	1	166.852	166.852	4.9	.0329
subjects w. groups	38	1293.888	34.05		
Repeated Measure (B)	1	4515.013	4515.013	234.561	.0001
AB	1	102.675	102.675	5.334	.0264
B x subjects w. groups	38	731.453	19.249		

There were no missing cells found.

The AB Incidence table

Repeated Measure:		pretests	posttests	Totals:
utilization	yes	24 1.542	24 18.417	48 9.979
	no	16 .906	16 13.156	32 7.031
Totals:		40 1.288	40 16.312	80 8.8

Table 8

One Factor ANOVA X_1: utilization Y_1: pretests

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	3.876	3.876	1.079
Within groups	38	136.568	3.594	p = .3056
Total	39	140.444		

Model II estimate of between component variance = .015

One Factor ANOVA X_1: utilization Y_1: pretests

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
yes	24	1.542	2.279	.465
no	16	.906	1.068	.267

One Factor ANOVA X_1: utilization Y_1: pretests

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
yes vs. no	.635	1.239	1.079	1.039

Table 9

Pretest 1 - Post-test 1

A repeated measures analysis of variance was conducted with pretest 1 and post-test 1 scores comparing the imagery utilization students with those who did not use imagery. The results of which are shown in table 10.

Results show the continued significance of effect for the repeated measure between pre-test 1 and post-test 1 with $F(1,40)=59.235$, $p<.0001$. The interaction effect between imagery utilization/non-imagery utilization and pretest 1/post-test 1 was not significant at $F(1,40)=3.984$, $p=.0531$.

Anova table for a 2-factor repeated measures Anova.

Source:	df:	Sum of Squares:	Mean Square:	F-test:	P value:
utilization (A)	1	18.802	18.802	4.299	.045
subjects w. groups	38	166.198	4.374		
Repeated Measure (B)	1	140.45	140.45	59.834	.0001
AB	1	9.352	9.352	3.984	.0531
B x subjects w. groups	38	89.198	2.347		

There were no missing cells found.

The AB Incidence table

Repeated Measure:		Pretest1	Test1	Totals:
utilization	yes	24 .292	24 3.5	48 1.896
	no	16 0	16 1.812	32 .906
Totals:		40 .175	40 2.825	80 1.5

Table 10

Combined Tests

At the beginning of the experiment both groups were given pretests for formula knowledge and for problem solving these scores were combined to create a combined pretest score. The results of a one factor ANOVA showed no statistically significant difference between imagery utilization students non-imagery utilization students and for results of combined pretests ($F=1.079, p>.05$). See table 12.

One Factor ANOVA X_1 : utilization Y_1 : pretests

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	3.876	3.876	1.079
Within groups	38	136.568	3.594	p = .3056
Total	39	140.444		

Model II estimate of between component variance = .015

One Factor ANOVA X_1 : utilization Y_1 : pretests

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
yes	24	1.542	2.279	.465
no	16	.906	1.068	.267

One Factor ANOVA X_1 : utilization Y_1 : pretests

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
yes vs. no	.635	1.239	1.079	1.039

Table 11

Combined Pretests - Combined post-tests

A repeated measures analysis of variance was conducted with combined pretests and combined post-tests scores comparing the imagery utilization students with those who did not use imagery. The results of which are shown in table 12.

Means on the pretest for the imagery utilization were higher than the non-imagery utilization group. There was no significant difference between experimental group and the control group before treatment since $F(1,40)=1.079$, $p=.3056$(Table 11). Results show the continued significance of effect for the repeated measure between combined pre-tests and combined post-tests with $F(1,40)= 234.561, p<.0001$. The interaction effect between imagery utilization/non-imagery utilization and combined pretests/combined post-test was significant at $F(1,40)=5.334, p=.0264$.

Anova table for a 2-factor repeated measures Anova.

Source:	df:	Sum of Squares:	Mean Square:	F-test:	P value:
utilization (A)	1	166.852	166.852	4.9	.0329
subjects w. groups	38	1293.888	34.05		
Repeated Measure (B)	1	4515.013	4515.013	234.561	.0001
AB	1	102.675	102.675	5.334	.0264
B x subjects w. groups	38	731.453	19.249		

There were no missing cells found.

The AB Incidence table

Repeated Mea...		pretests	posttests	Totals:
utilization	yes	24 1.542	24 18.417	48 9.979
	no	16 .906	16 13.156	32 7.031
Totals:		40 1.288	40 16.312	80 8.8

Table 12

Multi-step Problems

As there was no pretest for multi-step problem solving (test 4) a one factor ANOVA was used. The results showed statistically significant difference between imagery utilization students for results of test 4 ($F=2.102, p=.0071$). See table 13.

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	15.504	15.504	7.236
Within groups	38	81.42	2.143	p = .0106
Total	39	96.924		

Model II estimate of between component variance = .696

One Factor ANOVA X_1: utilization Y_1: Test4

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
yes	24	1.896	1.74	.355
no	16	.625	.885	.221

One Factor ANOVA X_1: utilization Y_1: Test4

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
yes vs. no	1.271	.956*	7.236*	2.69

* Significant at 95%

Table 13

PICTORIAL USE

Multi-step Problems

In the correcting of the test an interesting pattern arose in which the students who drew at least one pictorial, when solving the problems on test 4 seemed to do better than those that did not. Once again as there was no pretest for multi-step problem solving (post-test 4) a one factor ANOVA was used. The results showed highly statistically significant difference between students who drew pictorials and those who did not draw pictorials for results of test 4 ($F=2.102, p=.0071$). See table 14 .

One Factor ANOVA X_1: pictoral Y_1: Test4

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	1	17.005	17.005	8.086
Within groups	38	79.919	2.103	p = .0071
Total	39	96.924		

Model II estimate of between component variance = .753

One Factor ANOVA X_1: pictoral Y_1: Test4

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
yes	22	1.977	1.772	.378
no	18	.667	.907	.214

One Factor ANOVA X_1: pictoral Y_1: Test4

Comparison:	Mean Diff.:	Fisher PLSD:	Scheffe F-test:	Dunnett t:
yes vs. no	1.311	.933*	8.086*	2.844

* Significant at 95%

Table 14

Discussion:

For the sample of basic adult education students depicted in this investigation, the results of this study suggest that encouraging the formation of an image accompanied with verbal mediators to represent the main concept in a scientific rule facilitate both rule recall and problem-solving. Significant effect was found between the experimental and control groups and combined pre-test/combined tests $p=.0416$. Although not all four post-test produced significant results, the one for direct recall with p-values of 0.0667 approached significance. Formula recognition with p-value 0.0112 produced significant results. This mixed result is not in complete agreement with the bulk of research. Scruggs,Mastropieri,Levin,and Gaffery (1985); Mastropieri,Scruggs,and Levin (1986);Morrison and Levin(1989) found that the mnemonic condition produced superior recall of science concepts. It is possible that a larger student sample could have produced significant results for rule recall, or that the students uninitiated in imagery required a more comprehensive treatment for recall to be more effective. It is also possible that as the imagery approach was designed to teach both process skills and facilitate rule recall, the rule recall was not given sufficient emphasis.

The highly statistical significance of multi-step problem test results p=.0071 suggests that process learning is facilitated to a greater extent by this approach. For many educators, this process learning is a more important outcome than content learning. The only test which did not approach statistical significance was the test on one step problem-solving. This is because both groups after instruction found the problems presented little difficulty. This meant that the test instrument was not difficult enough to detect any variation in problem-solving ability. A second more sensitive test instrument was devised to evaluate the student's problem-solving ability. The test instrument involved the solving of multi-step problems. The results were consistent with those of Gabel and Sherwood (1983) and Levin,Rosenheck and Levin (1988) who found that a mnemonic imagery approach facilitated problem solving.

We have noted that Antonietti's results (1991) support the position that visual images encourage productive thinking,especially in problems where a number of variables require simultaneous consideration,and,correlatively,the usage of these images can overcome tendencies toward mechanization in problem solving. These research positions achieved by

Antonietti play a large explanatory role for the results of this present thesis in multi-step problem solving. For the adult education subjects of this thesis,particular emphasis is placed on problem solving throughout the term as well as in this experiment. This concentrated work in problem solving contributed to the successful results of both the experimental and control groups in one-step problem solving. The multi-step problem-solving test was quickly devised to take a more sensitive measure after what seemed,at first,an anomalous result in the first problem-solving test. The multi-step problem test did challenge students and the high statistical significance of the results from the experimental group fit the improved problem-solving conditions attributed to the use of visual imagery by Antonietti.

In a brief comparison with Antonietti's findings,the multi-step problem test of our experiment would require a kind of productive thinking that would transform the problem situation in unusual but effective ways. The visual anagrams of the formulas provided visual representation that encourage the imaginative manipulation of the problem situation and help students move away from a tendency toward mechanical application of formulas. As well, Kabanova-Meller (1971) attributes a positive role to imagery in problem solving in so far as it allows students flexibility in usual manipulations of the problem elements.

Gabel and Sherwood (1983),using four different instructional strategies, had their most significant improvements in problem solving with the construction of memory structure "images" in analogies.Our visual anagrams could certainly be categorized as pictorial analogies for process thinking and,similar to Gabel and Sherwood's results, our pictorial analogies to the formulas contribute to significant results in high level problem solving. In a similar vein ,Kaufmann (1979),in a study involving 44 secondary students ,also found evidence that pictorial analogies play a meditation role in problem solving . In a latter study, Kaufmann (1985) reports that visual presentations will facilitate problem-solving performance. He describes imagery as having the most important function in the initial phase of the problem-solving process. If a student is able to make a simultaneous consideration of the whole problem field by a set of mental imagery ,there is less likelihood that such a student will fall into the tendency of examining single elements as a solution to the problem. In respect to Kaufmann's key elements for the use of imagery in problem solving,our pictorial analogies were presented at the initial stage of the unit on formulas and related problem solving and students in the experimental group had the opportunity of considering the problem field in a holistic fashion through the pictorial imagery of the formulas.

The most promising aspect of our present study has been its locus in a major research field to isolate variables in the use of imagery that contribute to a learner' problem-solving success. Our present results offer an increment to high level problem-solving techniques,one that helps students break the reliance on formulas as a mechanized way of thinking.

The utilization of imagery by students in the study to facilitate both rule recognition to a significant degree and problem-solving of multi-step problems to a very significant degree. Test of direct recall approached significance with a p-value of 0.0531. This is some what consistent with results on McIntosh(1986) who found main effect for imagery utilization ($F(1,51)=5.56, p=.05$). It is possible that a larger student sample similar to McIntosh's would have produced significant results. The study does provide additional evidence that students who report using imagery will perform better on a rule recall test than those students reporting no imagery use. The observation is consistent with findings of Paivo(1971). With McIntosh's study it serves to extend the generalizibility of Paivo's hypothesis to include the recall of scientific rules. The multi-step problem solving test was highly statistical significant with a p=.0071. Gabel and Sherwood (1983) found that students with high mathematics anxiety profit by methods that contain supportive material that is not mathematical in nature. As high mathematics anxiety might easily describe most of the students in an adult upgrading course this might explain the results of this study.

High or low imagery rating on the five-point rating scale from the Marks Vividness of Visual Imagery Questionnaire resulted in only four students of the forty being rated as low imagery. With such a small number any conclusions about the effect on recall or problem-solving ability would be suspect. There was no effect due to gender on recall or problem-solving ability .

As with any teaching technique, results may vary due to student attitudes. This imagery techniques was developed with my own adult basic education class in 1993. During that time, many of the anagrams were originated and visual images were developed. The use of visual imagery proved to be positive and enjoyable when introduced as a part of regular class instruction.

From the results of this study some interesting questions for possible further research arose. Would the use of student generated imagery have been more effective for adult learners? The statistical significance of post hoc analysis of the use of pictorials during problem solving gives rise to another question. If students were required to draw representations of the problem to be solved would performance on tests be improved?

The study of the effects of imagery generation on science instruction has implications for its designers. The major implication of this research is that the incorporation of mnemonic imagery techniques into the design of science curricular materials for adult learners will facilitate greater learning in process skills involved in formula applications with multi-step problem solving.

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APPENDIX

CONTENTS

DEFINITIONS

Uses of Machines

1) A machine can change the size of the force.

2) It can change the direction of the force.

3) It can change the speed with which the force is applied.

Mechanical Advantage how much your effort is multiplied by the machine.

Ideal Mechanical Advantage(IMA) is the mechanical advantage a machine has if there is no friction.

Actual Mechanical Advantage(AMA) is the mechanical advantage a machine has if there is friction.

Simple machine is a device that changes the force used to do work.Examples:levers , pulley,inclined plane,wedge,screw and wheel,and axle.

Complex machine are devices made of two or more simple machines.

DEFINITIONS

Efficiency is the ratio of work that goes into a machine to work that comes out;also a comparison of actual mechanical advantage with ideal mechanical advantage.

Block and tackle is a system of pulleys used to raise a heavy object with a small amount of effort.

Work is defined as what is done when a force causes an object to be displaced.

A joule (j) is the work done when one newton (n) of force acts through a distance of one meter(m).

Power is the rate at which work is done.

Power depends on the following three factors:(1) the force applied, (2) the distance through which the force moves, and (3) the time during which the force is applied.

Formula

$$IMA = \frac{\text{Force arm}}{\text{Load arm}}$$

$$AMA = \frac{\text{Load}}{\text{Force}}$$

$$IMA = \frac{\text{Force distance}}{\text{Load distance}}$$

$$\text{Efficiency} = \frac{\text{Work out}}{\text{Work in}}$$

$$\text{Efficiency} = \frac{\text{Actual Mechanical Advantage}}{\text{Ideal Mechanical Advantage}}$$

$$\text{Work} = \text{force} \times \text{force distance}$$

$$\text{Power} = \frac{\text{Work}}{\text{time}}$$

$$\text{Power} = \frac{\text{force} \times \text{force distance}}{\text{time}}$$

$$IMA = \frac{\text{Horizontal distance}}{\text{vertical distance}}$$

Story

Ring, Ring

Betty: Hello.

June: Hi Betty. This is June. Did you hear about Pat?

Betty: No.

June: Well, you know how he's always saying "I'm a hooked dude on vehicle doctoring."

Betty: Yes. What a laugh. I remember when he came over and fixed my clock. He said "Power fasteners fix devices on time." Of course the clock didn't work the next day and I did not phone work on time.

June: I remember he was arguing with your kids that "Ice milk, a favourite appreciated over lemonade anytime. But we're getting off the topic. At the morning break he was bragging to his boss about how fast they could load a truck with fuel barrels.

Betty: Well, of course. Egos are mainly an over inflated male apparition.

June: After break Pat yells "all men are loading on fuel." Well he had barely pulled away with the loaded truck. Some barrels fell off. Pat walked fast from danger but not fast enough.

Betty: What do you mean?

June: The fuel blew up. Luckily they knew emergencies would occur over work injuries and were prepared. Now Pat is in the hospital where interns might administer first-aid over local anaesthetic.

Betty: Why didn't you tell me this earlier. I have got to go to the hospital and see if my brother's all right. Bye June.

June: Bye Betty.

Problems Chapter 16 & 18

1) A 100N force acts 12m the fulcrum to lift a load of 400N which acts 3m from the fulcrum.Find the ideal mechanical advantage,actual mechanical advantage,and efficiency.

$$IMA = \frac{\text{Force arm}}{\text{Load arm}} = \frac{12m}{3m} = 4$$

$$AMA = \frac{\text{Load}}{\text{Force}} = \frac{400N}{100N} = 4$$

$$\text{Efficiency} = \frac{AMA}{IMA} \times 100\% = \frac{4}{4} \times 100\% = 100\%$$

2) A pully system lifts a 80N weight 1m when a force of 20N is applied through 4m.Calculate the work-in,the work-out,the IMA, the AMA,and efficiency.If the weight is lifted in 10 seconds what is the power required?

Work-out= load X load distance
= 80N X 1m = 80N-m

Work-in = Force X force distance
= 20N X 4m = 80N-m

$$IMA = \frac{\text{Force distance}}{\text{Load distance}} = \frac{4m}{1m} = 4$$

$$AMA = \frac{\text{Load}}{\text{Force}} = \frac{80N}{20N} = 4$$

$$\text{Efficiency} = \frac{\text{Work-out}}{\text{Work-in}} = \frac{80N\text{-}m}{80N\text{-}m} \times 100\% = 100\%$$

$$\text{Power} = \frac{\text{work}}{\text{time}} = \frac{80N\text{-}m}{10 \text{ sec}} = 8 \text{ watts}$$

3) An incline plane 3m high and 15m long has an ideal mechanical advantage of?

$$IMA = \frac{\text{Horzontal distance}}{\text{Vertical distance}} = \frac{15m}{3m} = 5$$

4) If a pulley system lifts a 100N weight a vertical distance of 10m in 5 seconds calculate the power required.

$$\text{Power} = \frac{\text{force X force distance}}{\text{time}} = \frac{100N \text{ X } 10m}{5 \text{ s}}$$

Work-sheet

1) What is the efficiency of a block and tackle that lifts a 555 N resistance a height of 1m when an effort of 80 N moves through a distance of 10m?What is the input work?output work?

2) A 500-N cart is rolled up a 20-m plank to a platform 5 m off the ground by an effort of 150 N parallel to the plank.Find(a) the ideal mechanical advantage,(b) the actual mechanical advantage (c) the input work, (d) the output work,and (e) the efficiency.

3) What load is lifted by a lever with a 3-m resistance arm when 24 N is applied to the 5-m arm?(Eff=100%)

4) What is the efficiency of a machine that does 160 N-m of output work with 200 N-m of input work?

5) An incline plane 3m high and 15 m long has an ideal mechanical advantage of?

6) How much effort is required to lift a resistance of 72 Kg to a height of 6.o m with a pulley system that has a efficiency of 80%?

7) A 50-N weight is placed 2m from the fulcrum of a lever.In order to balance the lever , a weight of 80 N must be placed on the other side at what distance? (Eff=100%)

8) What is the efficiency of a pulley if an effort of 20 N through a distance of 10m lifts an 80-N through a distance of 2m?

9) A motor can lift a load of 825 N a distance of 5m in 2.5 sec.Compute (a)the work done and the power needed.

10) How much work is done by lifting 72 N a height of 6 m?

11) Find the IMA if the AMA is 4 and the efficiency is 80% .

Exercise 1
Underline the formulas found in the following telephone conversation.

Story

	Ring, Ring
Betty:	Hello.
June:	Hi Betty. This is June. Did you hear about Pat?
Betty:	No.
June:	Well, you know how he's always saying "I'm a hooked dude on vehicle doctoring."
Betty:	Yes. What a laugh. I remember when he came over and fixed my clock. He said "Power" fasteners fix devices on time." Of course the clock didn't work the next day and I did not phone work on time.
June:	I remember he was arguing with your kids that "Ice milk, a favourite appreciated over lemonade anytime. But we're getting off the topic. At the morning break he was bragging to his boss about how fast they could load a truck with fuel barrels.
Betty:	Well, of course. Egos are mainly an over inflated male apparition.
June:	After break Pat yells "all men are loading on fuel." Well he had barely pulled away with the loaded truck. Some barrels fell off. Pat walked fast from danger but not fast enough.
Betty:	What do you mean?
June:	The fuel blew up. Luckily they knew emergencies would occur over work injuries and were prepared. Now Pat is in the hospital where interns might administer first-aid over local anaesthetic.
Betty:	Why didn't you tell me this earlier. I have got to go to the hospital and see if my brother's all right. Bye June.
June:	Bye Betty.

Exercise 1.

Match the formulas and state application. Either: pulley. level, incline, or universal.

				Purpose
1.	IMA =	____	$\frac{W}{t}$	____________
2.	AMA =	____	$\frac{Fa}{La}$	____________
3.	IMA =	____	$\frac{Hd}{vd}$	____________
4.	IMA =	____	$\frac{Wo}{Wi}$	____________
5.	Eff =	____	$\frac{Fd}{Ld}$	____________
6.	Eff =	____	FxFd	____________
7.	W =	____	$\frac{FxFd}{t}$	____________
8.	P =	____	$\frac{AMA}{IMA}$	____________
9.	P =	____	$\frac{L}{F}$	____________

Pretest 1

In the pervious section a number of formulas were used.An example of one would be $S = \frac{at^2}{2}$ which is used to calculate the displacement of an object starting at rest when dropped.For this section the use of a number of formulas is also necessary.For the following terms state the formula(s).

Formula(s)

Actual Mechanical Advantage

Ideal Mechanical Advantage

Work

Power

Efficiency

Pretest 2

State formula use and show all calculations.

1) Calculate the ideal mechanical advantage of a lever if the load arm is 2m and the force arm is 12m.

2) The actual mechanical advantage of a machine is 3 and the ideal mechanical advantage is 4. What is the efficiency?

3) A pulley lifts a weight of 100N a distance of 2 meters calculate the work done.

4) What is the power required to perform 160 N-m of work output in 20 seconds.

5) What is the AMA of a machine that lifts a weight of 100 N with an effort of 20 N?

6) What is the IMA of an incline plane 20m long and 2m high?

7) A pulley system lifts a mass 2m when a force is applied through a distance of 10m what is the IMA?

8) What is the efficiency of a block and tackle that does 555 N-m of work and 800 Nm of work is inputed ?

9) How much power is needed to carry a 100-N box up three flights of stairs with a vertical height of 12m in 20 sec?

$P = \frac{W}{t}$, $W = f \times fd$, $IMA = \frac{Fa}{La}$, $IMA = \frac{Fd}{Ld}$, $IMA = \frac{Hd}{Vd}$, $AMA = \frac{L}{F}$,

$P = \frac{f \times fd}{t}$, $Eff = \frac{AMA}{IMA} \times 100\%$, $Eff = \frac{Wo}{Wi} \times 100\%$

Test 1

In the pervious section a number of formulas were used. An example of one would be $S = \frac{at^2}{2}$ which is used to calculate the displacement of an object starting at rest when dropped. For this section the use of a number of formulas is also necessary. For the following terms state the formula(s).

<u>Formula(s)</u>

Actual Mechanical Advantage

Ideal Mechanical Advantage

Work

Power

Efficiency

Test 2

Show all calculations.

1) What is the efficiency of a block and tackle that does 200 N-m of work and 800 Nm of work is inputed ?

2) The actual mechanical advantage of a machine is 3 and the ideal mechanical advantage is 9. What is the efficiency?

3) A pulley lifts a weight of 100N a distance of 2 meters calculate the work done.

4) What is the AMA of a machine that lifts a weight of 200 N with an effort of 40 N?

5) What is the IMA of an incline plane 20m long and 2m high?

6) A pulley system lifts a mass 2m when a force is applied through a distance of 8m what is the IMA?

7) What is the power required to perform 160 N-m of work output in 20 seconds.

8) Calculate the ideal mechanical advantage of a lever if the load arm is 4m and the force arm is 16m.

9) How much power is needed to lift a 200-N box up a vertical height of 1.5m in 2 sec?

$P = \frac{W}{t}$, $W = f \times fd$, $IMA = \frac{Fa}{La}$, $IMA = \frac{Fd}{Ld}$, $IMA = \frac{Hd}{Vd}$, $AMA = \frac{L}{F}$,

$P = \frac{f \times fd}{t}$, $Eff = \frac{AMA}{IMA} \times 100\%$, $Eff = \frac{Wo}{Wi} \times 100\%$

Test 3

Match the formulas .

1.	IMA =	____	$\frac{W}{t}$
2.	AMA =	____	$\frac{Fa}{La}$
3.	IMA =	____	$\frac{Hd}{vd}$
4.	IMA =	____	$\frac{Wo}{Wi}$
5.	Eff =	____	$\frac{Fd}{Ld}$
6.	Eff =	____	FxFd
7.	W =	____	$\frac{FxFd}{t}$
8.	P =	____	$\frac{AMA}{IMA}$
9.	P =	____	$\frac{L}{F}$

Test 4

1) What is the efficiency of a block and tackle that lifts a 400N resistance a height of 2m when an effort of 50 N moves through a distance of 18m?

2) A 800-N cart is rolled up a 30-m plank to a platform 3 m off the ground by an effort of 80 N parallel to the plank.Find work out.

3) A 50 N weight is placed 2 m from the fulcrum of a lever, a weight of 80 n must be placed on the other side at what distance?

4) A motor can lift a load a distance of 5m in 2.5 sec with a power output of 800 watts .Compute (a) the work done and the force needed.

5) A load is lifted by a 90% efficient lever with a 3-m resistance arm when 24 N is applied to the 5-m arm?Find the AMA.

6) A force acts through a distance of 18m in 3 seconds to lift a load of 36 N to a height of 3.o m with a pulley system that has a efficiency of 80%.Find (a) the actual mechanical advantage (b) the input work, (c)and the power required.

$P = \frac{w}{t}$,$W = f \times fd$, $IMA = \frac{Fa}{La}$,$IMA = \frac{Fd}{Ld}$,$IMA = \frac{Hd}{Vd}$,$AMA = \frac{L}{F}$,

$P = \frac{f \times fd}{t}$,$Eff = \frac{AMA}{IMA} \times 100\%$,$Eff = \frac{Wo}{Wi} \times 100\%$

Vividness of Visual Imagery Questionnaire

Rating	Description
1.	'Perfectly clear and as vivid as normal'
2.	'Clear and reasonably vivid'
3.	'Moderately clear and vivid'
4.	'Vague and dim'
5.	'No images at all ,you only "know" that you are thinking of the object'

For items 1-4 ,think of some relative or friend whom you frequently see(but is not with you at present) and consider carefully the picture that comes before your minds's eye.

Item

1. The exact contour of face,head,shoulders and body.
2. Characteristic poses of head ,attitude of body,etc.
3. The precise carriage,length of step,etc.,in walking.
4. The different colours worn in some familiar clothes.

Visualize a rising sun.Consider carefully the picture that comes before mind's eye.

Item

5. The sun is rising above the horizon into a hazy sky.
6. The sky clears and surrounds the sun with blueness.
7. Clouds.A storm blows up, with flashes of lightning.
8. A rainbow appears.

Think of the front of a shop which you often go to.Consider the picture that comes before your mind's eye.

Item

9. The overall appearance of the shop from the opposite side of the road.
10. A window display including colour,shape and details of the door.
11. You are near the entrance.The colour,shape and details of the door.
12. You enter the shop and go to the counter.The counter assistant serves you.Money changes hands.

Finally, think of a country scene which involves trees,mountains and a lake..Consider the picture that comes before your mind's eye.

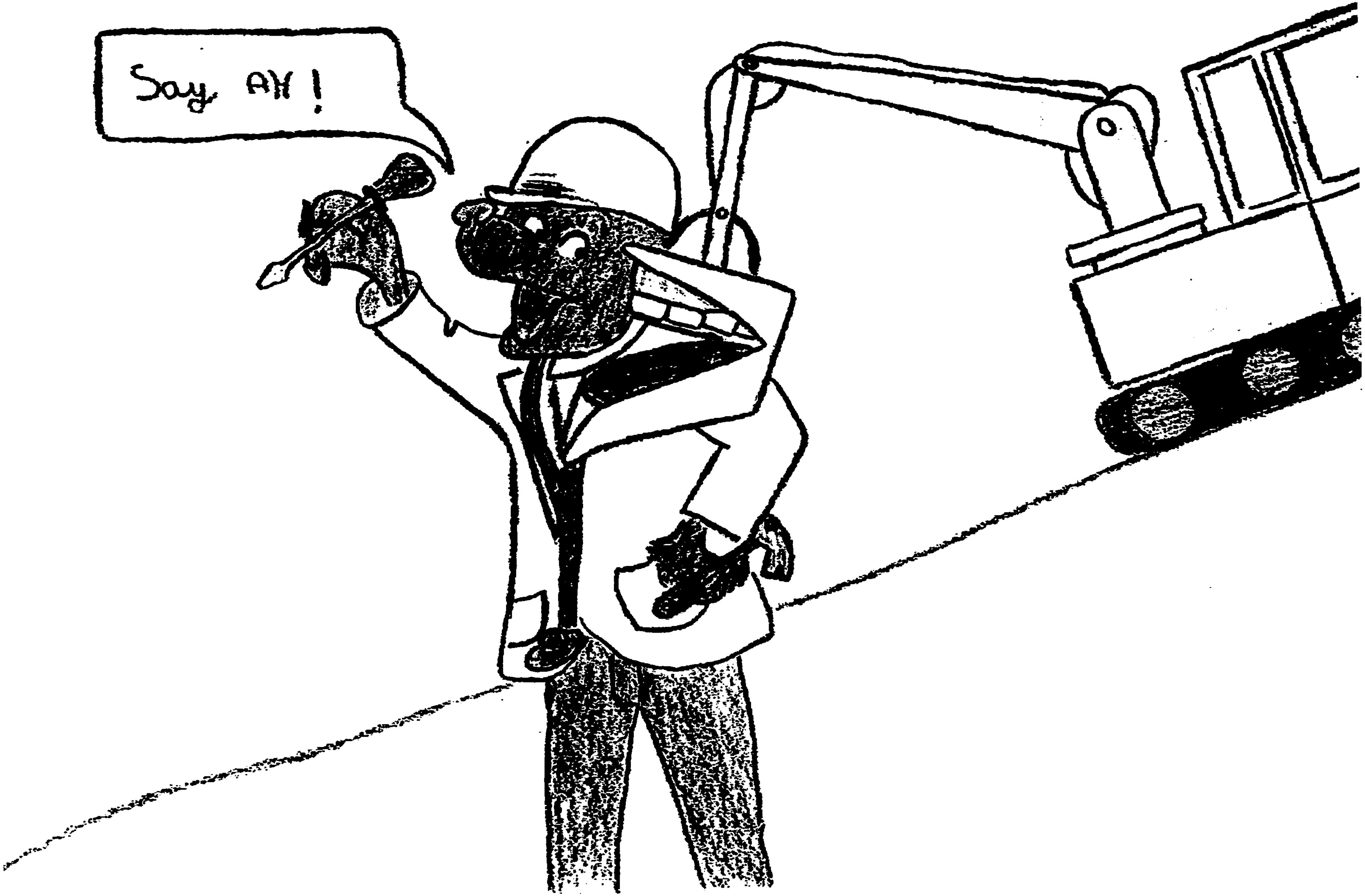
Item

13. The contours of the landscape.
14. The colour and shape of the trees.
15. The colour and shape of the lake.
16. A strong wind blows on the trees and on the lake causing waves.

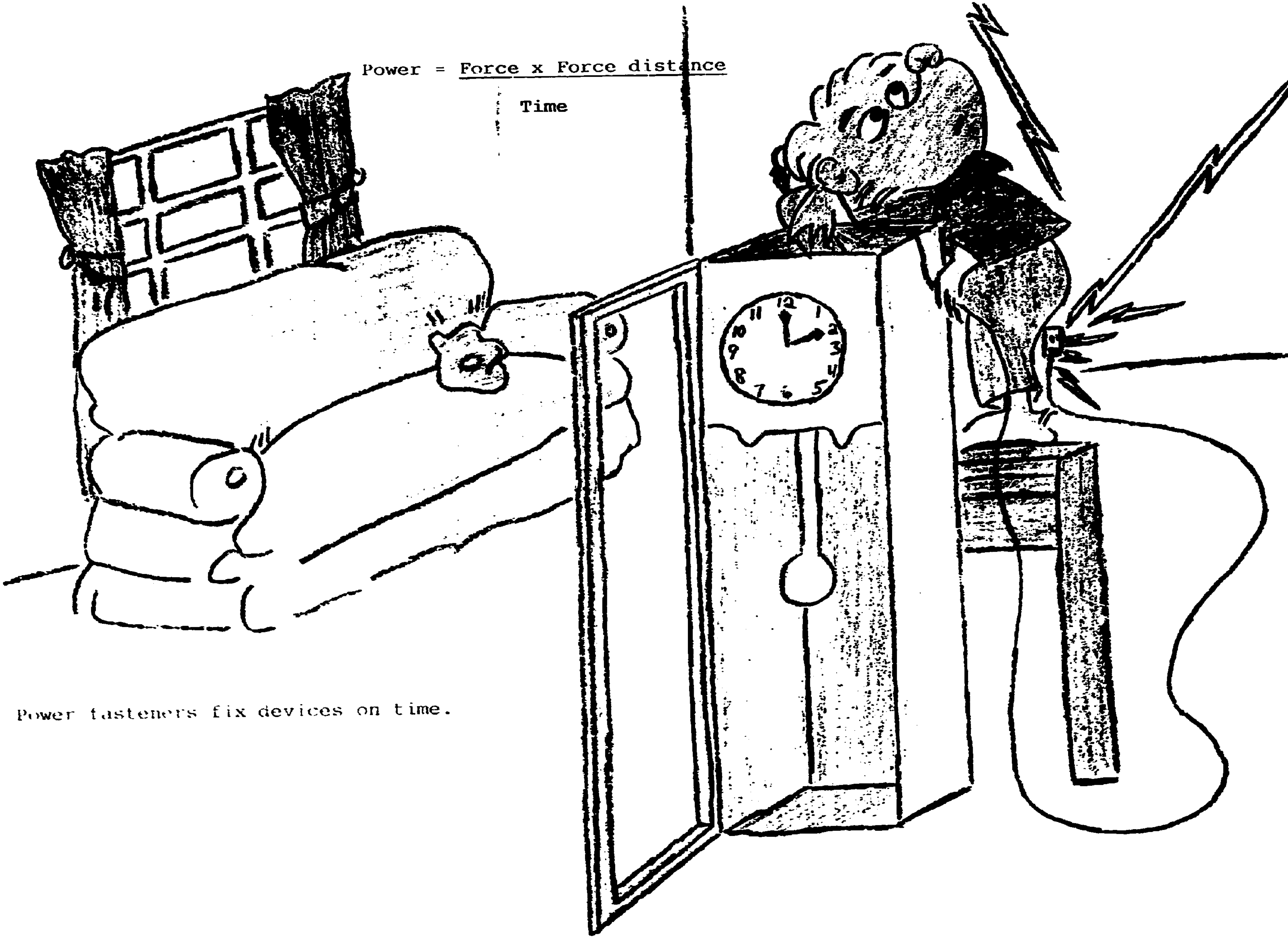
(Marks,1973)

IMA - Hd Vd

I'm a hooked dude on vehicle doctoring.

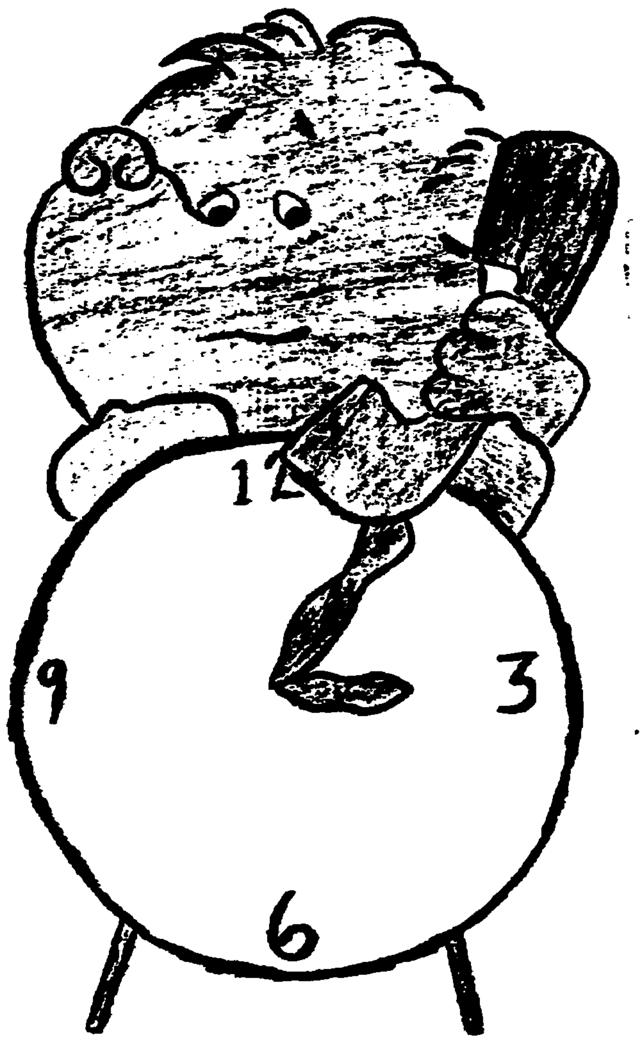


$$\text{Power} = \frac{\text{Force} \times \text{Force distance}}{\text{Time}}$$

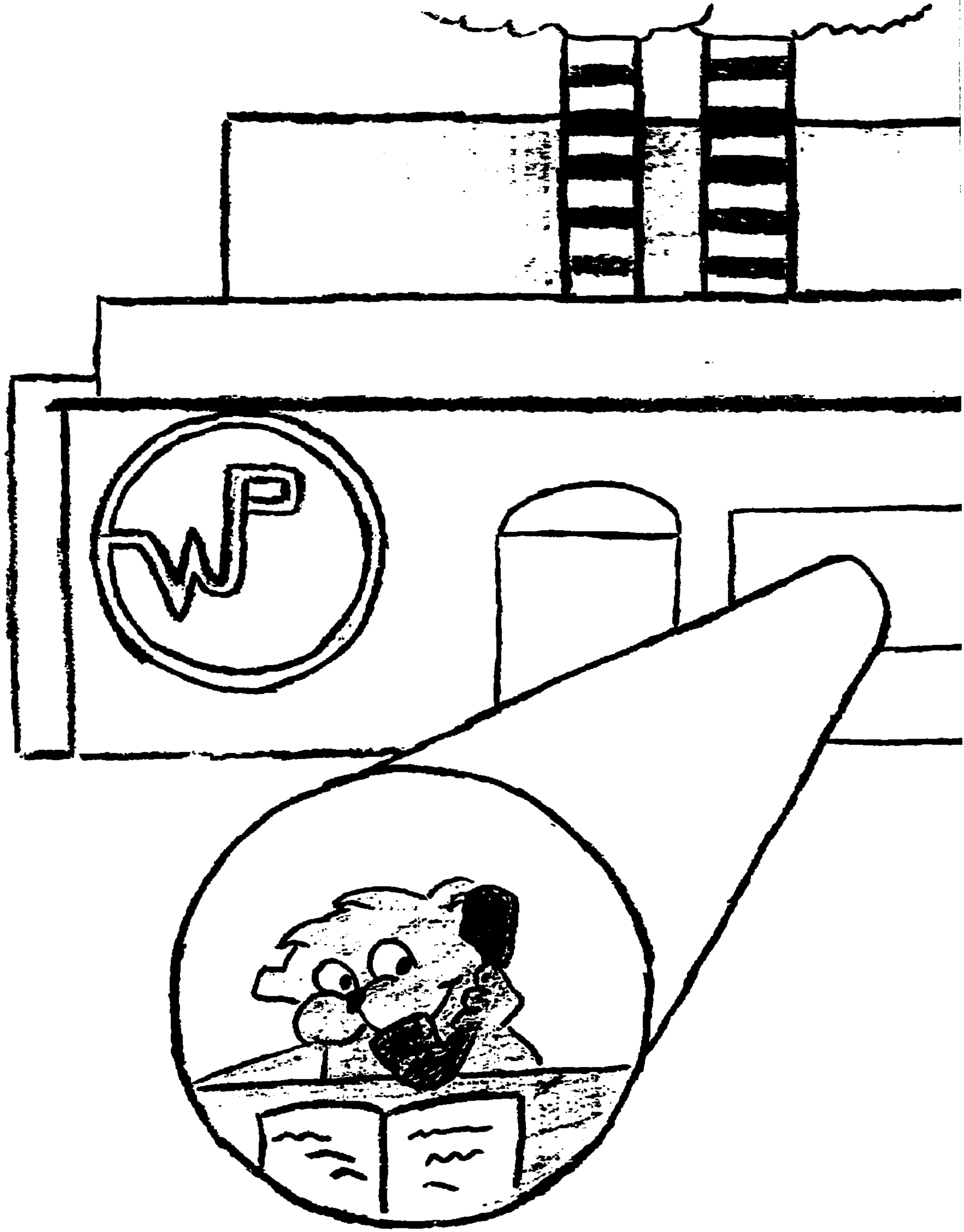


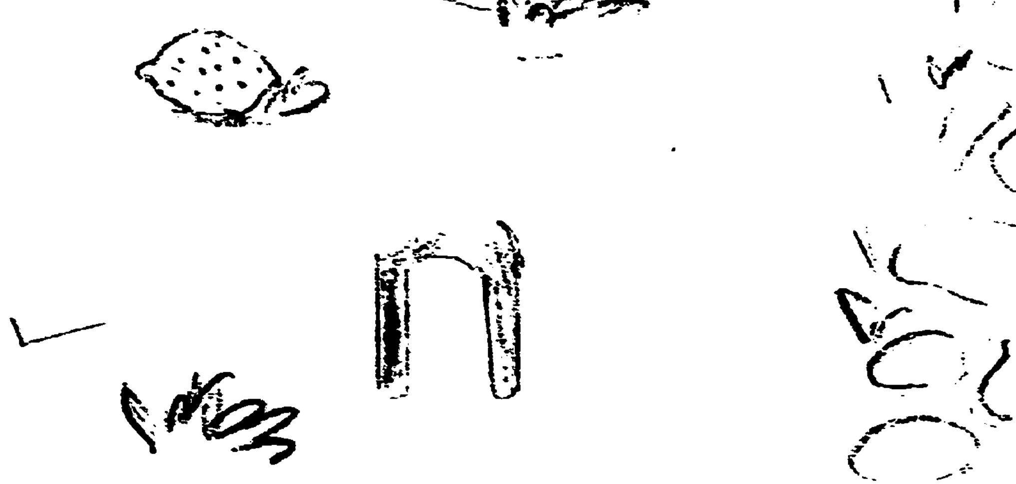
Power fasteners fix devices on time.

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$



Phone work on time.



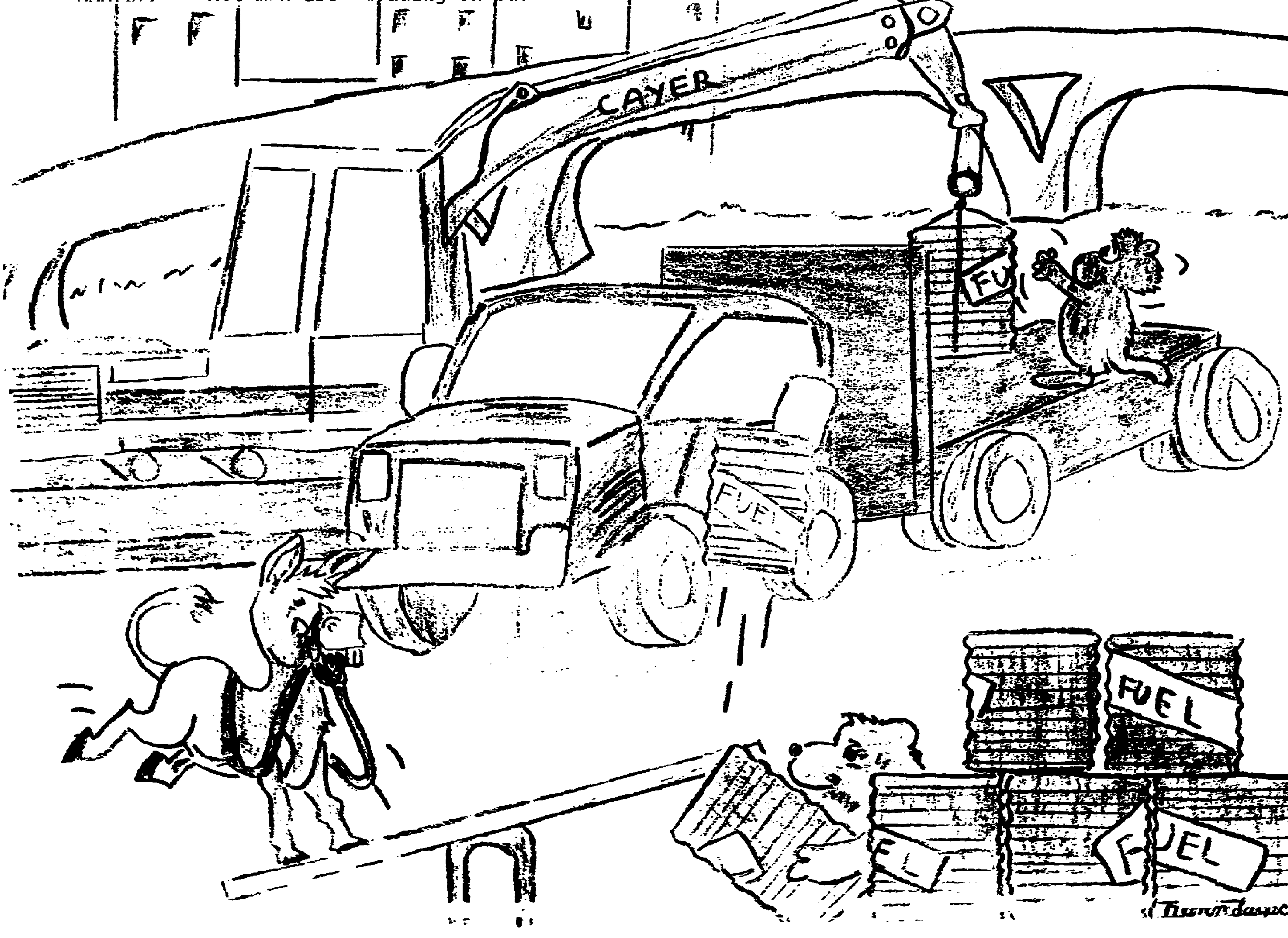


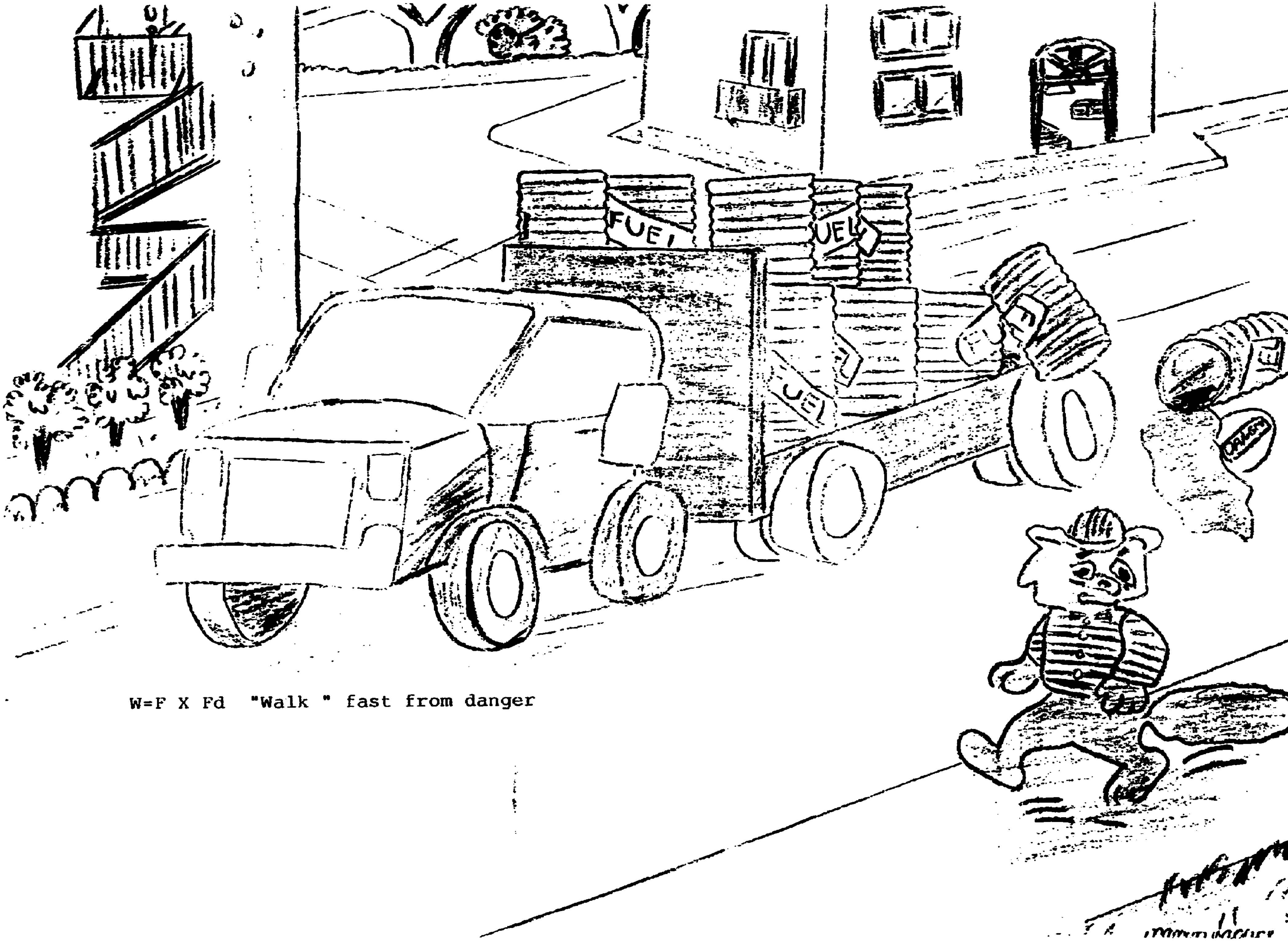
IMA=Fa/La

"Ice milk a" favourite appreciated over lemonade anytime.

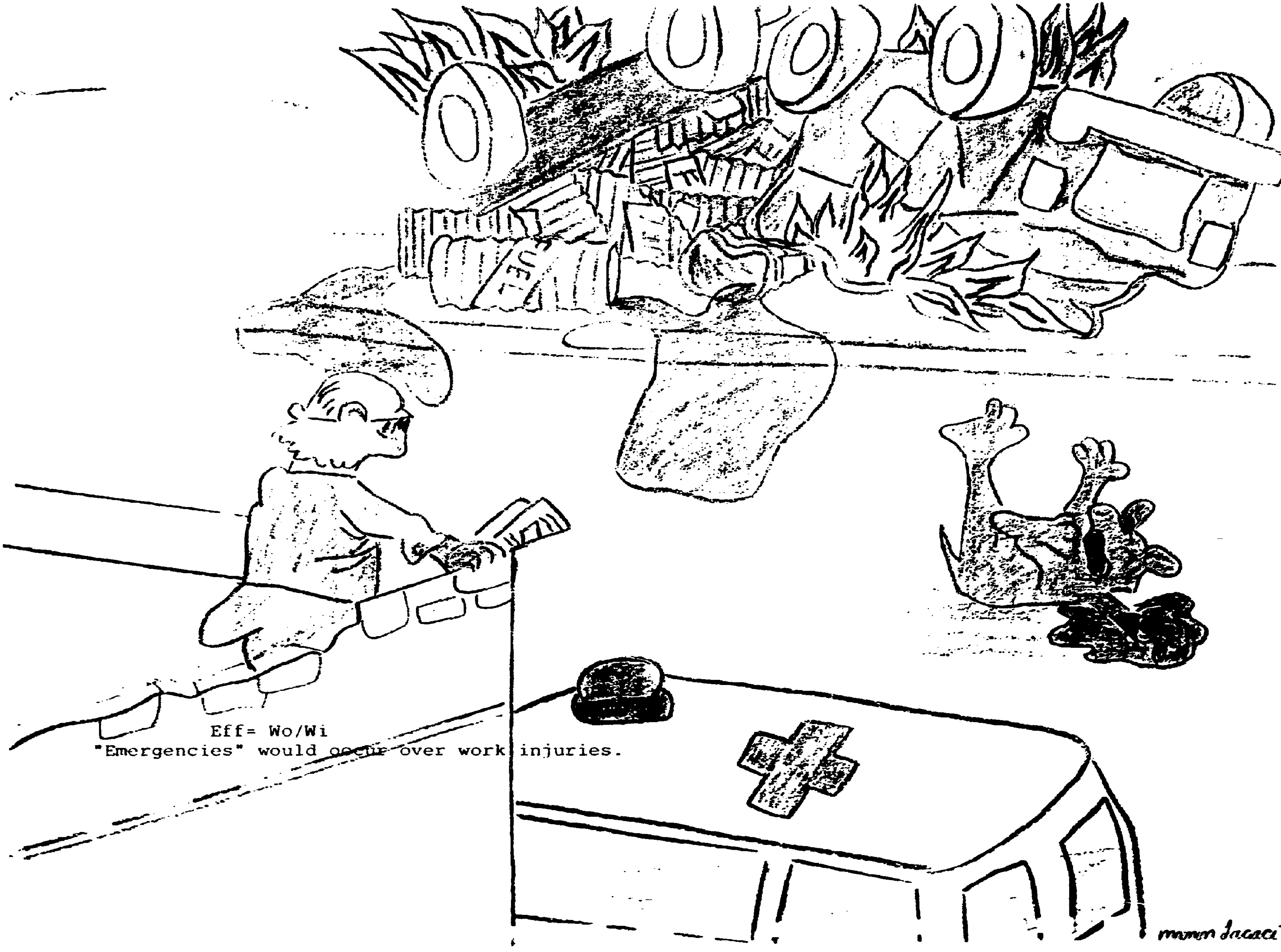
Ell AMA/IMA Egos are mainly an over inflated male apparition.

AMAZD,F "All men are" loading on fuel.

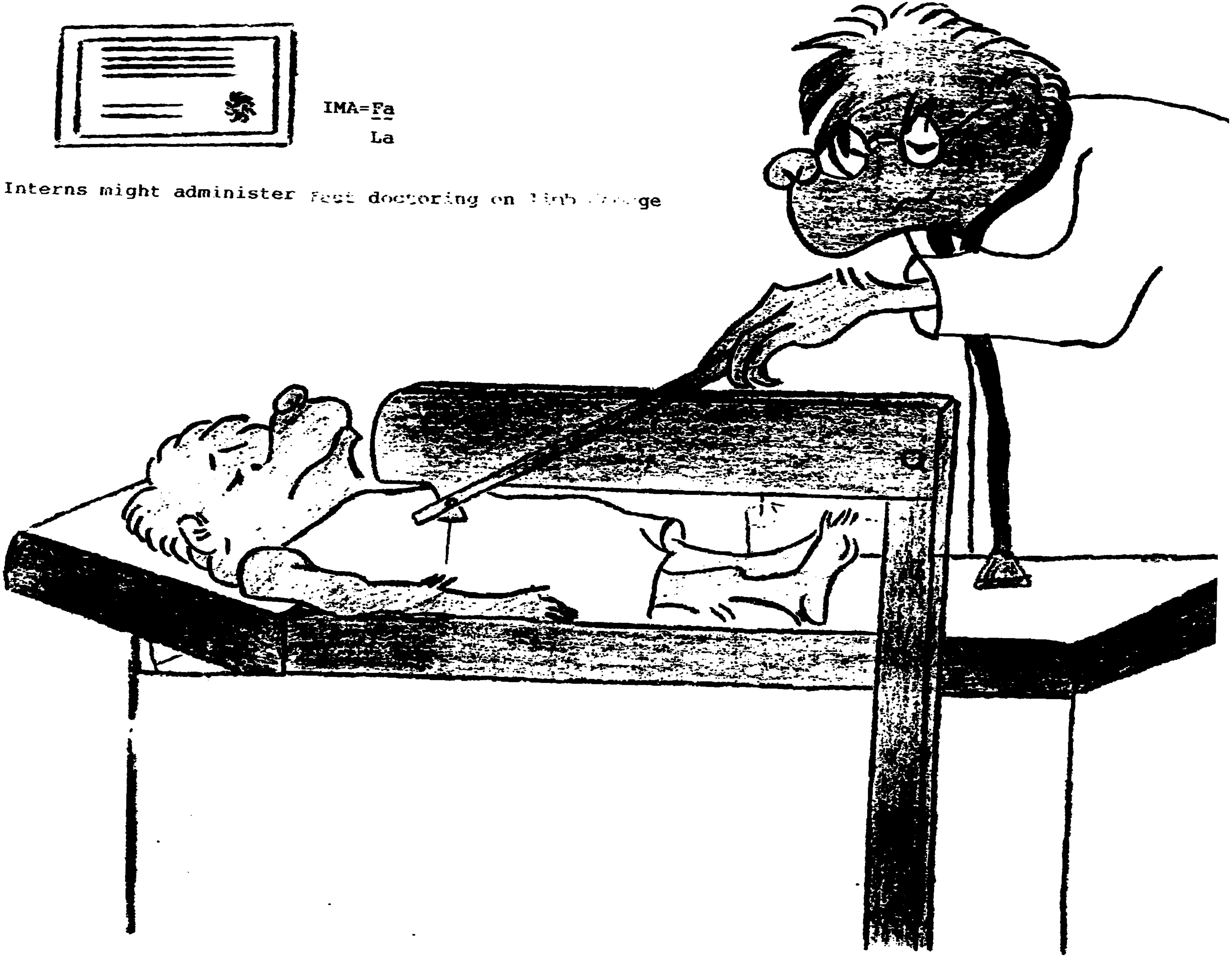




W=F X Fd "Walk " fast from danger



Eff= Wo/Wi
"Emergencies" would occur over work injuries.


IMA=Fa
La
Interns might administer fast doctoring on