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ABSTRACT

It is alleged by math teachers and their supporters that math problem solving actually transfers to skills in real or applied problem solving (RAPS). The purpose of this paper is to discuss the issue of math problem solving and the concomitant concept of mental discipline/transfer of learning. The mental discipline theory and evidence to support this theory is broached first, then the relationship between mental discipline and math problem solving is discussed. It is concluded that mathematics should be taught in public schools when there is high interest, high aptitude, or high need for this kind of learning. When math is taught, it should be taught well, integrating math theory as much as possible into the real world that surrounds students. Otherwise, the time spent in public schools that has been allocated to mathematics should be reallocated to the development of useful, relevant teaching in RAPS. (Contains 14 references.) (ASK)

MATH PROBLEM SOLVING AND MENTAL DISCIPLINE: THE MYTH OF TRANSFERABILITY*

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“Stand firm in your refusal to remain conscious during algebra. In real life, I assure you, there is no such thing as algebra.”

Fran Lebowitz
(c.1951–)
Quoted in *Time*, January 10, 1983

MATH PROBLEM SOLVING AND MENTAL DISCIPLINE:

THY MYTH OF TRANSFERABILITY

It is alleged by math teachers and their supporters (whom I shall refer to from now on as "math types") that math problem solving (the kind of problem solving found in such subjects as Algebra or Geometry) actually transfers to skill in real or applied problem solving (RAPS). The allegation that math problem solving transfers to real world issues is constantly made by individuals who wish to justify the expenditure of resources in public schools on math subjects (which are not, by the way, ARITHMETIC skills which are basic and should be required before promotion or graduation). The purpose of the present paper is to discuss the issue of math problem solving (MPS) and the concommitant concept of mental discipline/transfer of learning. I refer the reader to a different paper (Lemire, 1988) for a complete discussion of the conceptual model which differentiates math problem solving from real problem solving. For the purposes of this paper "mental discipline" means the unsubstantiated theory that by having acquired such cognitively sequential skills as mathematics or classical languages (Greek or Latin) there is carry over, or transfer, of learning to important real life creative skills such as are found in real and applied problem solving.

Kolesnik (1958) in his rather lengthy treatment of mental discipline, stated,

> The expression, mental discipline, has not always meant the same thing to all people, nor does it have a single, universally-accepted meaning today. As it is used in (his) book, it signifies nothing more than the phychological view that (people's) mental capacities can somehow be trained to operate more efficiently 'in general,' and that philosophical conviction that such training constitutes one of the chief

purposes of schooling, (p. 3).

Further, Kolesnik stated, "There is no single source to which one might turn for a dispassionate over-view of the subject. Mental Discipline In Modern Education is an attempt to fill this gap in educational literature," (p. vii).

Kolesnik's book, 30 years old now, tries to plug the cracking dike of the mental discipline theory. It will be the purpose of this paper to refute, to the extent that I can, Kolesnik's assertion which is a pure and accurate statement of the mental discipline/transfer of training assumptions.

Kolesnik differentiates the old mental discipline theory into three versions: (1) mental discipline (the older original term, though still used), (2) formal discipline (by which Kolesnik means "...strengthening or developing the powers of the mind by exercising them, preferably on difficult, abstract material, such as Latin, Greek and mathematics. For disciplinary purposes, the content of school subjects is held to be of secondary importance. It is their form which is thought to be exceptionally efficacious in the creation of minds able to operate well in any field of endeavor," p. 4). Kolesnik continues, "Of the three concepts in question, transfer of training (the third concept) is generally regarded today as the broadest. It refers to the application of knowledge, skills, habits, attitudes or ideals acquired in one situation--such as the physics laboratory--to another situation for which they had not been specifically learned--such as the kitchen, the farm, the machine shop or the algebra class. Whereas the possibility of transfer was once denied, it is now generally accepted as a sound principle...," (p. 4). I completely and wholeheartedly DISAGREE with this allegation. As the evidence will clearly show the assumption that mental discipline, formal discipline, transfer of training, or whatever it is called really takes place is simply not true and is scientifically UNSUPPORTED. As John Wayne would

have said to Mr. Kolesnik, "not hardly."

Is There Any Evidence To Support The Mental Discipline Theory?

A reasonable question the inquiring mind can now ask is, "Is there any evidence supporting the mental discipline theory?" Unhappily for the math types like Kolesnik the answer is NO. It will now be the purpose of the author to walk the reader through some of the experimental research on the mental discipline theory which has taken place since the turn of this century. Probably one of the earliest and most thorough studies of the mental discipline theory was completed by Thorndike (1924). Thorndike's study included over 8,000 students (a massive number for the time, considering there were no calculators then). Thorndike's report, in the Journal of Educational Psychology, takes up almost 100 pages (it was published in two parts). In his conclusion Thorndike stated:

> By any reasonable interpretation of the results, the intellectual values of studies should be determined largely by the special information, habits, interests, attitudes, and ideals which they demonstrably produce. The expectation of any large difference in general improvement of the mind from one study rather than another seems DOOMED TO DISAPPOINTMENT (emphasis added). The chief reason why good thinkers seem superficially to have been made such by having taken certain school studies is that good thinkers have taken such studies, becoming better by the inherent tendency of the good to gain more than the poor from any study. When the good thinkers studied Greek and Latin, these studies seem to make good thinking. Now that the good thinkers study Physics and Trigonometry, these seem to make good thinkers. If the abler pupils should all study Physical Education and Dramatic Art, these subjects would seem to make good thinkers, (p. 98).

More evidence against the mental discipline/transfer of training theory has been presented by Bransford, et. al., (1986) in an article on "Transfer of Training and Problem Solving." These authors concluded:

> We noted earlier that one way to characterize the effects of the student's long hours of practice is to assume that it strengthened some general "mental muscle" or "mental faculty." An alternative theory stresses the development and utilization of an appropriate knowledge base. These theories have important implications for teaching. If a student practiced remembering number strings yet makes little progress, a mere emphasis on trying to exert some "mental discipline" in order to "build mental muscle" would probably be less than useful. It would be more effective to help the student acquire knowledge that could provide a basis for encoding numerical information, and to help him or her automatize the ability to encode numerical information from the prespective of that domain (e.g., Schneider & Fisk, 1982; Schneider & Shiffrin, 1977), (p. 1079).

Probably the most persuasive current article which puts mental discipline/ transfer of training in proper subserviented place is one by Clark and Voogel (1985). The authors stated,

> One of the central purposes of all training is to provide knowledge and skills for <u>future</u> benefit to students. Most instructional designers assume that their students will be able to transfer the skills learned in a training setting and apply them to different problems in different settings. Yet, there is considerable evidence that much of what is learned can only be applied to problems that are similar to those experienced in training (Bransford, Nitsch & Franks, 1977; Cronbach & Snow, 1977; Mayer & Greeno, 1972; Royer, 1979). These transfer failures involve diverse types of learning tasks and learner populations.... An even more familiar

type of transfer failure is experienced by the child who achieves mastery of simple mathematical skills in the classroom but is unable to make change when sent to the store. Knowledge that is bound to specific application contexts and tasks represents an insidious and unsolved problem for training technologies. Most performance evaluations do not measure transfer beyond the training setting. When transfer is evaluated, it seems often to fail (Cronbach & Snow, 1977).

Further:

These transfer failures are a curiosity since the literature on transfer is one of the oldest in education. It includes diverse milestones such as comments in Plato's Dialogues, and extensive discussion by Thorndike and Woodward at the turn of the century, and an excellent synthesis of the first 50 years of research in this century by Osgood in 1949 (Ellis, 1965).

Since the 1960s, interest in transfer of training research has diminished steadily.... Many believe that Osgood adequately summarized all that instructional designers needed to know about transfer. However, there is recent and disturbing evidence of transfer failure in many training programs that were developed using behaviorally based instructional design technology (Cooley & Lohnes, 1976; Cronbach & Snow, 1977; Royer, 1979). It seems that our technology for ensuring the transfer of skills to problems and settings beyond where instruction occurred is defective, (p. 114).

Other research exists that supports the negation of the mental discipline/ transfer of training theory. Stanic (1986) studied the role of mental discipline theory in the history of mathematics education. The author argued that we now remember mental discipline theory only as a caricature of what it was; and,

moreover, it persists among both teachers and researchers. Connors (1983) has described how education has moved away from mental discipline and "toward the immediate instructional goal of simple mechanical correctness."

Cormier and Hagman (1987) have summarized the information on transfer of training in a historical context:

> The study of transfer of learning has a dominant place in the early history of experimental psychology. The pioneering studies of Thorndike and Woodworth, in 1901, advance the theory of transfer as a function of identical elements in common between learning and transfer tasks. In various forms, this theory is still with us, where a major concern is how to conceptualize these elements....
>
> Early research (e.g., by E.S. Robinson, the "similarity" factor in Retroaction, in 1927, and by R.W. Bruce, Conditions of Transfer of Training, in 1933) initiated subsequent research in which the conditions of transfer, such as the amount of initial training or difference in task difficulty, were studied. Osgood's work, in particular his 1949 publication, was significant in dealing with the theoretical analysis of the conditions of transfer and providing a model (the Osgood Transfer Surface) for predicting task-to-task transfer in terms of positive, zero, and negative effects. During this period, the 1948 Psychological Bulletin paper by Gagne', Foster and Crowley had considerable impact in providing a basis for the measurement of transfer effects.... (p. xii).

Just What Is Mental Discipline?

"Mental discipline" is simply the old term for what we now know to be abstract/sequential/left-brain dominant learning preferences. I believe that the mental discipline theory is still alive and kicking because it is favored culturally and socially by the analytical orientation of Western philosophy

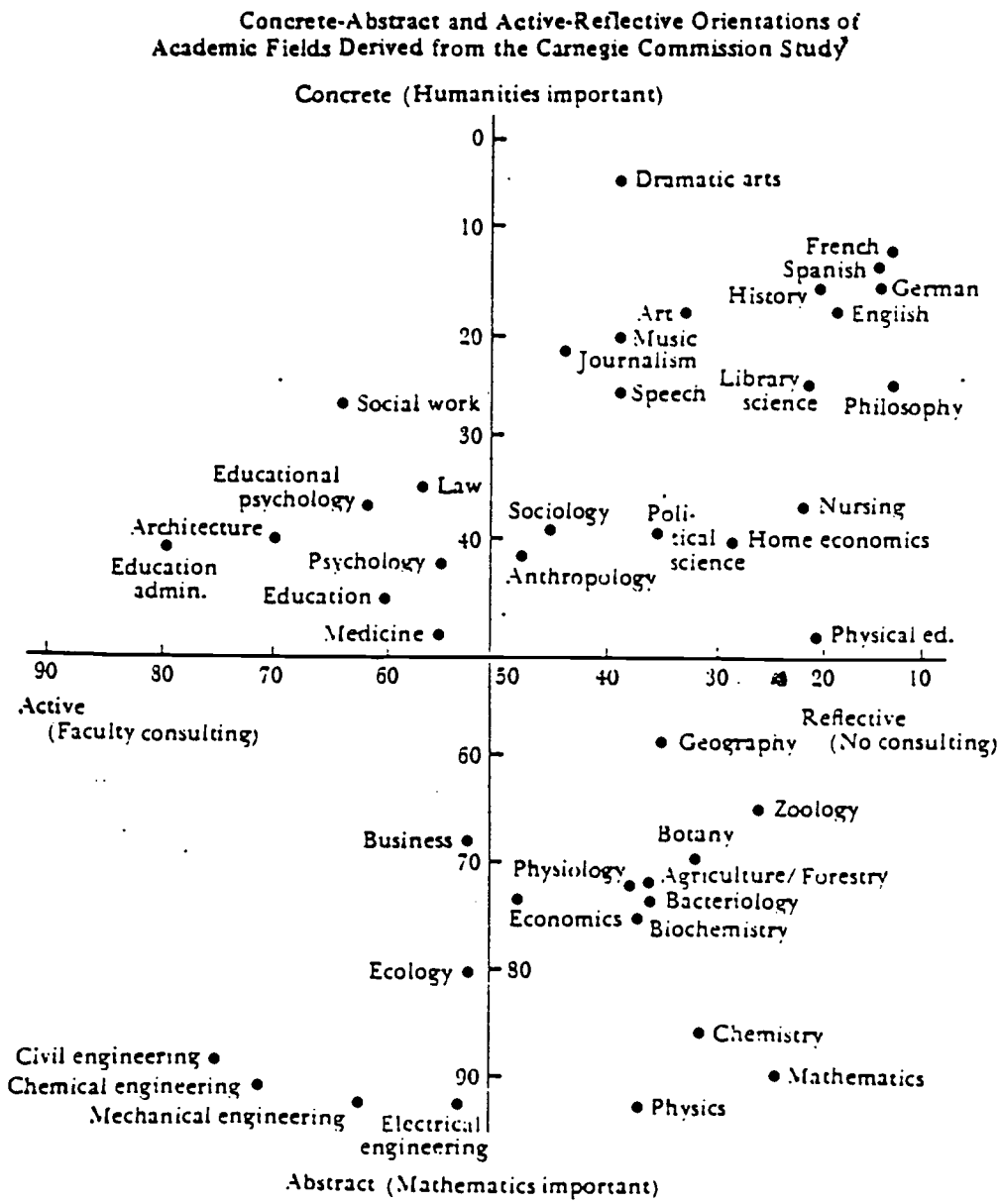
and Western science. However, from the point of view of wholistic education mental discipline is by definition a limited, simplistic, and reductionistic approach to learning, aside from being incorrect. To advocate the use of mental discipline as a form of instruction for the sequential learners is fine. However, sequential learners represent only about one half the population of learners (even though the current research in this area is sketchy). The rest of the learning population (including the present author) are random learners. Those of us who are random learners take profound exception to the dominance by sequentials of American institutionalized education. There are several models of learning and cognitive styles which indicate that there are generally four kinds of learners (at least all of these models utilize a quadrant paradigm: Gregorc (1979), Kolb (1981), McCarthy (1985), Canfield (1988), and others.) Figure One presents a model of Kolb's quadrant learning style model. While the evidence supporting these models is limited, each of them has in common the idea of specialized predilections based on some form of learning or cognitive orientation.

Mental Discipline Is Really Math Problem Solving

To this author, mental discipline/transfer of training is really math problem solving (using the model by this author in another context, 1988). So what does math problem solving do? A typical math problem goes as follows: "A boy went to a spring with a five quart and a three quart measure to procure exactly four quarts of water. How did he manage? (Limitations to this problem: you may not use a third container, you may not make any marks on the container, and you may not estimate amounts.)" The correct answer to this problem from the point of view of this author is: Who cares? This kind of problem solving may well improve one's ability to do MATH problem solving. This kind of skill is fine for people who are interested in, more able in math, or need to use

Figure One

Kolb's Model of Learning Styles



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these kinds of math skills. But to rationalize the excessive time spent on math training in the average public school by saying that math problem solving transfers to real life skills is an absurd assertion for which there is little or no evidence, and has not been for half a century. Let me suggest a paradigm that might put this math issue into manageable terms: First of all, we should call math "calculation and computation." Second, we should differentiate between "arithmetic" (addition, subtraction, multiplication and division) and "mathematics" (algebra, geometry, trigonometry, and calculus). Arithmetic is a lower form of math which is a basic skill and should be required learning in all public schools. Mathematics is NOT a basic skill and, in fact, is not really important knowledge at a personal level for most people. There are only three conditions where it is appropriate to learn mathematics: (1) high interest, (2) high aptitude, and (3) high personal relevance. The time has come to basically reorder the public school curriculum's priorities and replace failed elements (such as math) in school with a curriculum that has three levels: the 3 R's (reading, 'riting, 'rithmetic), the 4 R's (resourcefulness, responsiveness, responsibility and respect) and SABs (subject area basics). The standard by which any element of the curriculum is taught should be the Rule of Relevance (and the correlates of the Rule of Relevance are high interest (HI), high aptitude (HA) and high need (HN)).

I am NOT saying that there is no place for math (as differentiated from arithmetic) in the public school curriculum. What SHOULD determine the place of math in the curriculum is personal importance (relevance) to the learner. Arithmetic is important, basic, and necessary. Yet remember that a "basic skill" is something that we cannot, as productive citizens, do without. Any average person can do without algebra, geometry, trigonometry, and calculus.

At the same time, mathematics is one of the ways we understand the world. Yet in the past 100 years (during the formation of the present American public school system) math has been given a priority that it does not deserve. I would like to see the math priority altered, such that creativity and real life problem solving are given the allocation of time and resources that is now spent on math in the curriculum. Math skills (algebra, geometry, trigonometry and calculus) are nice for those who want them but should NEVER be required within the normal public school curriculum.

The Implications of the Lack of Mental Discipline For The Curriculum

To summarize, there is little evidence that mental discipline/transfer of training really exists, yet math teachers, public school administrators and school boards act like it does exist. Mental discipline is really a form of math problem solving (MPS), which is a left-brained, sequential, genetically programmed orientation that we have little direct control over. There are a number of other problems associated with the math curriculum of any average American public school:

(1) Rote mechanics are over-drilled into students without important conceptual understanding. Most of the time students taught this way are both disinterested and unwilling (compulsory education requires attendance or jail, so selecting math over jail is an understandable choice).

(2) There is a fundamental lack of relevance pertaining to math instruction in schools. That is to say, math is taught under threat (You had better do it!) without any major consistent or systematic effort to make math make sense or relate math to the real world (when is the last time any normal person needed to divide fractions outside of a classroom?).

(3) Specious assumptions abound in math teaching, not the least of which is the mental discipline myth. There is also the myth that "You might use this knowledge some day." Get real. Or the also pervasive "What if you decide to become an engineer?" ploy exists. Not likely for most of us. The percentage of engineers in the world's population is infinitesimal. There are certainly not enough engineers around to rationalize the squanderous waste of educational resources that are currently spent on math teaching.

(4) The analytical orientation of Western science and philosophy gives math analyticality a priority it does not deserve in this day and age. Happily, education does seem to be moving away from the reductionistic analytical orientation to a more appropriate wholistic model (also called the integrative model) of teaching. This change is a relief that is long overdue.

(5) Math teachers and the advocates of the teaching of math have an OBLIGATION to deal with the aforementioned issues (#1-4) and are not doing so. This avoidance,at best,is understandable and,at worst,is negligence.

As has been indicated, it is constantly asserted that math problem solving leads to a greater ability to solve real life problems. It is an obligation of the math teachers of the world not only to demonstrate their rather specious hypothesis by experimental support, but also to demonstrate their belief to such a degree that new experimental evidence will outweigh the unfavorable conclusions of a half century's worth of experimental findings. Since there is little or no relationship between math problem solving and real life problem solving then math teachers have a professional obligation to deal with their fantasy-- a fantasy which math types steadfastly maintain in the face of evidence to the contrary. Exposing the myth of transferability also has implications for the school curriculum. Since arithmetic is a basic skill (one a productive citizen needs) then promotion and graduation decisions should

be made upon the basis of the acquisition of skills, and not simply time spent in school as is presently the case.

So What Do We Replace Math With?

I believe that a basic skills curriculum has three components: the 3 Rs (reading, 'riting, and 'rithmetic), the 4 Rs (responsibility, respect, resourcefulness and responsiveness) which come from Individual Education schooling (Pratt and Mastroanni, 1985), and subject area basic skills (for example, in American Government knowing that and how the three branches of a representative government work together). Thus, once the 3 Rs have been mastered relevant options should be provided to parents. Students who master arithmetic may then CHOOSE to go further with their math studies. However at no time should mathematics be a required part of the public school curriculum. The time which has been spent on math should be spent on a curriculum of high personal relevance. For example, instead of squandering one hour per day, 180 days per year for the six to seven years of middle and high school instructional time, this time should be spent on a curriculum offering education and training in real or applied problem solving and critical thinking. If these proposed changes were made then students would have the choice of leaving school with important skills that deal with real life, rather than superficial and substantively irrelevant training in mathematical thinking.

What Are Real Life Problems?

There are many varied real life problems that need to be solved, both individually and culturally. These are problems of a directly personal relevant nature, not circumlocutive applicability. Consider the real problems of (1) people like Nixon, Noriega and Marcos, (2) alcoholism, (3) garbage (of both the mental and physical kind), (4) drug use (including tobacco and caffeine, (5) pollution (of the mental and physical kind), (6) overpopulation, (7) spouse and child abuse, (8) incest, (9) homelessness, (10) war in general

Figure Two

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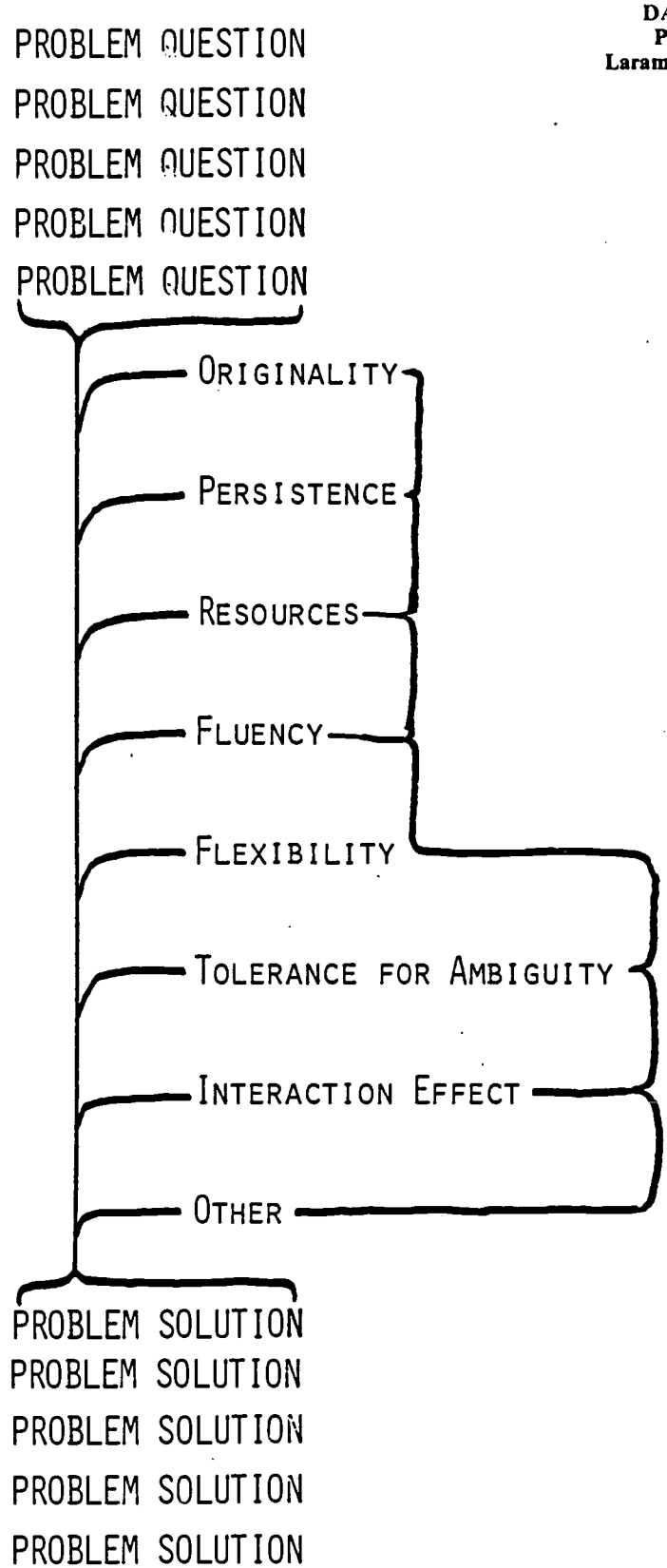

HOLOGRAPHIC PROBLEM SOLVING

A TWO-DIMENSIONAL FLOW-CHART FOR A THREE-DIMENSIONAL PROCESS

and nuclear war specifically, not to mention greed, corruption, stupidity, and ignorance, to name just a few of the more important problems. The potential of real solutions to real problems are shaped, to a large degree, by the problem question which is formed. This consideration is presented graphically in Figure Two. Consider, for example, the "problem" of divorce. The fact of the matter is that divorce is NOT the problem. BAD MARRIAGE is the problem. You can not possibly solve a problem until you can understand it. Divorce is simply one real solution to the actual problem of bad marriage. It would be far more valuable to society and to the individuals who compose that society if people were trained in real problem solving rather than frivolous math problem solving. If a person can solve algebra word problems there is little or no tangible effect on his/her personal life. If we as a world do not deal with a problem like the proliferation of nuclear weapons and the danger of nuclear war then there may be no world left to solve problems in.

Summary

The essential problem with the mental discipline/transfer of training myth is that its proponents are asserting, in the words of Walt Disney, that elephants can fly. It is clear that math skills are a primary left brain function and that real or applied problem solving is primarily a right brain function (ignoring for the moment the essential interdependence of hemispheric functioning, as per Torrance, 1984). It is my belief that math transfer, mental discipline, or whatever it is called does not exist and has never existed. For the myth of math transfer to be correct the right brain would have to become the left brain. This is not likely to happen. God gave humans, in Her Infinite Wisdom, two halves of the brain that are supposed to work together, not replace each other.

As for the assertion that mental discipline and transfer of training really exist, the burden of proof falls to those who advocate such a position. As far as can be determined from the evidence that exists to date there is little or no support for the mental discipline theory and has not been for half a century. The myth of mental discipline can also be intuitively rejected. As Thomas Jefferson said, some truths are self-evident. The transfer of math problem solving skills to real life situations is NOT one of those truths. In summary, mathematics, as a specific discipline, should only be taught in public schools when there is high interest, high aptitude, or high need for this kind of learning. In addition, when math is taught it should be taught well, integrating math theory as much as possible into the real world that surrounds students. Otherwise, the time spent in public schools that has been allocated to mathematics should be reallocated to the development of useful, relevant, teaching in real or applied problem solving.

"The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old questions from a new angle, requires creative imagination and marks real advance in science."

Albert Einstein

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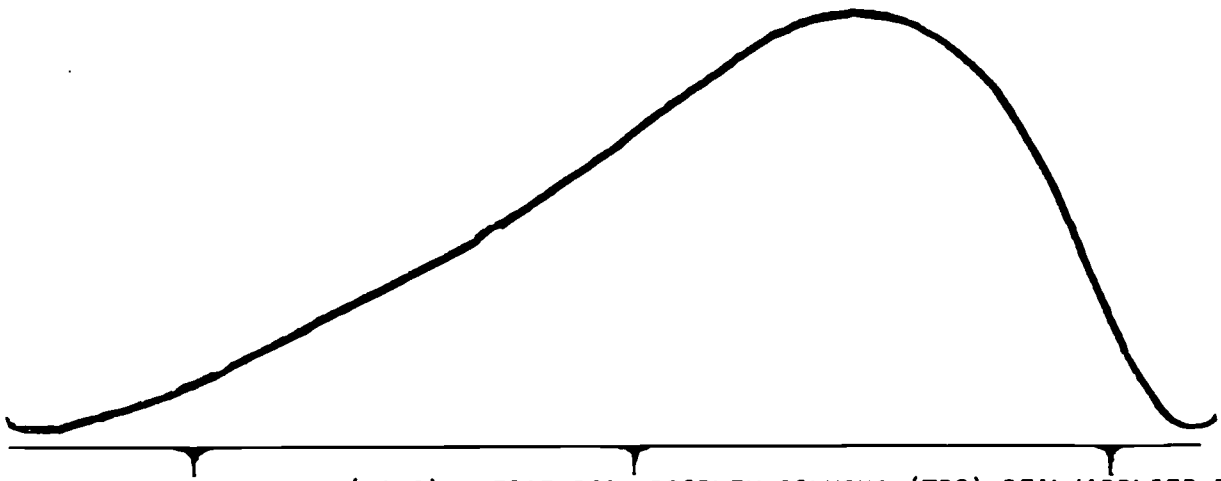
Appendix A

The Problem-Solving J Curve



MATH PROBLEM SOLVING (MAPS) THEORETICAL PROBLEM SOLVING (TPS) REAL/APPLIED PS (RAPS)

Low Relevance High Relevance

The Problem Solving J Curve proceeds along a continuum from low relevance to high relevance (left to right).

Examples MPS:	Examples TPS:	Examples RAPS:
Division	Physics	Garbage
Fractions	Nuclear War	Pollution
Algebra		Divorce
		Bad Marriage

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HOLOGRAPHIC PROBLEM SOLVING
From: A Three-Dimensional Model of Problem Solving: The PS Cube

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