The Role of Frame Analysis in Enhancing the Transfer of Knowledge

Barry Krusch

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Note to the Reader:

This paper was originally written for a course in Hunter College, and I've extensively rewritten it since then. The real thrust of the paper, after some important introductory material, begins on page 6.

Does previous experience transfer to new situations, and if so, in what circumstances? To educators, this phenomenon of *transfer* is key. Without transfer, one has educated or been educated only in the rather limited domain of that which has immediately occurred in the classroom: a contrived situation that seldom occurs twice. As transfer increases, so does the value of education. In an Information Age, where the amount of knowledge that can be known grows exponentially (and with it the amount of knowledge that has to be taught), increasing the efficiency of education is an issue of paramount importance.

Concern with this issue is not new, however. Prior to experiments by Thorndike and Woodworth in the early part of this century, a theory known as the *doctrine of formal discipline* was widely accepted. According to this theory, *general* principles of formal reasoning could be taught implicitly by selecting material for learning which subjected the mind to these principles. Latin and Math were widely considered to be useful in this regard. Students would take courses not for content, but because they "exercised the mind." These habits would then *transfer* at a later time to other disciplines, such as science. The clear implication of this hypothesis that transfer was readily obtainable was that education should be *global* to achieve maximum efficiency. (Detterman, 1993).

But this optimistic theory was challenged by Thorndike and Woodworth in 1901. The psychologists trained subjects to estimate the area of *rectangles*. Subsequent tests involving different *polygons* (triangles and circles) revealed errors 90% as large as the errors before training. On this task, it appeared that transfer of the general skill of *estimating the area of polygons* was very difficult to obtain. After analyzing their results, Thorndike and Woodworth concluded that improvements in a single mental function rarely brought about an equal improvement in another function.

Surprisingly, Thorndike and Woodworth reached this *general* conclusion even though 1) the nature of the task given was very *specific* [estimating the area of geometrical shapes], and 2) subjects required between 1,000 and 2,000 practice trials to achieve improvement on rectangle area estimation [introducing a *fatigue* source of error]. Still, many subsequent studies seemed to confirm Thorndike's findings. According to Detterman (1993), since the Thorndike and Woodworth experiment there have been hundreds of experiments reaffirming the same point. Transfer is very difficult to obtain. (*See also* Singley and Anderson (1989), who reached a similar conclusion).

But even though the theory of *general* transfer was discredited, the notion of transfer *in any form* was not, not even by Thorndike, who introduced as an alternative to the theory of formal discipline the *theory of identical elements.*

According to this theory, transfer would occur only when *specific* component skills in the *target* area (*to be* learned) were isomorphic with those present in the *base* (*that which was* learned). Learning Latin would perhaps not help a student learn Chemistry, but it might help her learn Spanish (a language with elements common to Latin): "[o]ne mental function or activity improves others . . . because it contains *elements [in] common* to them . . . [K]nowledge of Latin gives increased ability to learn French because many of the facts learned in the one case are needed in the other." (Thorndike, 1906, pp. 243, emphasis supplied).

However, "elements in common" is a vague expression. As Gick and Holyoak (1987) perceptively noted, an "escape clause" was implicit in the linguistic formulation of this hypothesis, since "common" elements could be construed in a general way to include not only *perceptual features* but also *categories, procedures, principles,* and even *emotional attitudes*; in other words, commonality existed at not just the level of immediate sensation, but at a deeper level, that of cognitive processing (where the meaning perceived is in large part a function of the *processing* through which the meaning was derived). Commonality could exist at low, middle, and high levels, depths as well as surfaces, depending on the minds and approaches of the student and teacher.

This was a different angle: identity does not exist in and of itself, but only as a function of the *frame* of reference through which the information is perceived. The "common element" restriction fails because, at some level of abstraction, and through some frame of perception, *everything* has *something* in common with every other thing. For example, learning Math and Latin share the common element of "having to study." Biology and Chemistry share the common element of "scientific method." And so forth. From this angle, the view was completely different, and from this perspective, many psychologists saw the potential for transfer where others saw none. Thus, Cormier and Hagman (1987, at p. xi), after citing several reviews of the topic, stated that "[t]ransfer of learning . . . is pervasive in everyday life, in the developing child and in the adult." According to these authors, the magnitude and generality of the effects produced by previous learning upon performance in new learning tasks suggested that transfer phenomena should assume a critical importance in psychology. The theory of transfer had come full circle.

Once the dust created by term-mongering ("general" vs. "specific" transfer, "near" vs. "far" transfer, etc.) settles, it is clear that *some* transfer must take place at least *some* time. Take the words on this page as an example: even if we were all trained to read **`in the mono-spaced Courier font, like this`**, it is reasonable to expect from everyday experience that when we are presented with material **in the proportional-spaced Garamond font, like this**, we can still comprehend the text. We can even read text presented in other styles, such as **bold,** *italic*, or shadow**.** This means that the learning and recognition of text elements such as lettershapes does not take place merely at the *local* level of *lettershape-as*-(FONT: **Times**)-(SIZE: **14 point**)-(STYLE: **Plain**), but, more importantly, at the *global* level of *lettershape,* a more *schematic* level which can be exemplified by any example which follows the form. This ability to see patterns (via the perception of similarities through the filters of differences) allows us to make sense of the world, and explains why certain experiences in our lives quickly grow familiar. To use a mundane example, we learn where to shop for food, how to get to the store, and how to pay for the groceries, and don't worry that the available parking spaces have changed each trip, nor that new items are on the shelf, nor that unfamiliar cashiers greet us at the check-out counter. The accumulation of knowledge acquired from *past* shopping experiences is transferred without difficulty to present shopping experiences (Gick and Holyoak, 1987), a phenomenon which cuts across *experience* in general.

Indeed, observation of the world around us shows us that the ability to recognize patterns and form generalizations leads to a "practice makes perfect" phenomenon: because of this phenomenon, pilots are trained on flight simulators (Rose, Evans & Wheaton, 1987), soldiers fight in war games, actors rehearse, prospective surgeons experiment on cadavers, architects work from models, pro football teams draft from colleges, prospective employees are filtered for consideration based on their prior experience, and college courses require prerequisites. In fact, one entire educational domain, law school, has as its explicit aim not to "teach the law," but teach the student how to "find the law," an ability derived from past experiences. Transfer exists, so much so that when it exceeds its legitimate boundaries, we refer to it as *negative* transfer, the well-known psychological phenomenon of *overgeneralization:* the young boy who calls every adult "daddy"; the young girl who is given "night," "light," and "right" to spell, and then spells "hight"; or the nationalist who believes that all Japanese people are "ruthless."

In point of fact, there *has* to be some degree of transfer, if only because recognizable and predictable patterns exist in the scientific and mathematical domains of reality. A ball released from the hand will fall to the ground whether one is in Paris or Rome, and a one in a million chance is "not a good chance" whether one is afraid of being hit by lightning or anxious to win the lottery. 2 + 2 = 4 whether the quantity is apples or dollars, and being an historian as opposed to a biologist does not shield one from the difficulty of formulating well-reasoned hypotheses.

The scientific and mathematical disciplines frequently show us that reality has a structure which, skeleton-like, is then filled out by particular phenomena. When we recognize the similarities which cut across differing surfaces (i.e. seeing the phenomenon of gravity in a dropping ball or orbiting planet), we can be said to have seen the *deep structure* of reality, a concept that over the years has cut across "hard" sciences like physics and into "softer" sciences such as the field of psycholinguistics, where it was made famous by linguist Noam Chomsky. Chomsky's theory held that, like physical laws, all languages have *deep* structures, which are instantiated through transformation rules into *surface* structures. As the dropping ball reveals gravity, so does the sentence reveal grammatical deep structure. For example, the deep structure "John hit ball" converted by the *passive* transformation results in the surface structure "The ball was hit by John," while conversion by the *active* transformation will produce "John hit the ball." (Mayer, 1992). As Chomskian psycholinguists noted, transformation rules should be seen as *universal*, transcending all cultures.

Thus, the rationale for the existence of transfer at the *physical* and *linguistic* levels. But transfer needs to be understood at the *psychological* level of *information processing*, because any transfer of knowledge will occur only after the processing of information has taken place. Along with the critical concept of deep structure popularized by Chomsky are at least three other key concepts in understanding how people think from the (respective) fields of cognitive science, artificial intelligence, and cryptography: *schemas*, *frames*, and *encoding*.

Schemas, Frames, and the Encoding of Knowledge

Transfer is not the only issue in educational psychology which rests on the premise that reality has a deep structure. In fact, a more well-known area of educational psychology, *schema* theory, is also predicated on the existence of this concept. (Reed, 1993, at p. 42) described a schema as

> [A] cluster of knowledge representing a particular generic procedure, object, percept, event, sequence of events, or social situation. This cluster provides a skeleton *structure* for a concept that can be *instantiated*, or filled out, with the detailed properties of the particular instance being represented. For example, a schema for the American Psychological Association annual meetings would contain the

standard properties of a scientific conference such as its location, date, attenders, session types, and the length of presentations. . . . (1st emphasis supplied)

Schemas select and organize incoming information into an integrated, meaningful framework. People change new information to fit existing concepts, and in the process, knowledge becomes more coherent to the individual. Schema theory explains an important aspect of thinking: its *organization*.

That schemas are used to organize thinking is not mysterious. Consider the world, and its multifaceted, vast store of information contained in libraries, organized with schematic classification schemes such as the Dewey Decimal system. Now imagine the Library of Congress and its millions of books, journal articles, and newspapers, etc., and simultaneously imagine that its cataloging system is not only entirely destroyed, but that, in addition, all the books within it are randomly reshelved. Now how does one find the information one requires? The chaff has hidden the wheat. While in reality the information may be only twenty yards away, it is, functionally speaking, unavailable. The same phenomenon obtains in the filing systems of our minds, which ordered by schematic structures, enable semantic perception itself.

Schema theory now plays a prominent role in the field of education, second perhaps only to behaviorism as a structuring paradigm upon which entire approaches of education (e.g. whole language) have been built. For example, teachers schooled in the *whole language* approach understand that a student will be able to fill in (instantiate) the blanks in the words contained in the following sentences due to the student's preexisting schemas which are keyed in by the known words in the sentence, and the sentences which surround them:

Ed took his daugh____ to the super_____ .
He bou___ her some foo_ to ea_ .
They ate hamb____s and fr___ fr___ , with bak___ bea__ on the side.

Schema theorists maintain that whether or not we understand something is in large part due to our existing background knowledge; that for which we have a schema (cooking), we understand. That for which we do not (nuclear physics), we do not. For this reason, transfer is more likely when we learn material in a domain with which we are already familiar, base learning being rooted in prior knowledge.

Schema theory is closely related to a second information processing construct which has an impact on the issue of transfer, the concept of the *frame* (*see* Bateson, 1972: Goffman, 1974; Minsky, 1975), a cognitive filtering system that can key in items of a text or a situation as meaning "X," while simultaneously excluding other interpretations. There are *interpretive* frames (the way we see things [decoding]), and *exemplifying* frames (the way we present things [encoding]). *All* language is embedded within exemplifying frames; to take the most obvious example, the words that appear on this page have been encoded within the frame of ENGLISH, and within that frame, the frame of ACADEMIC WRITING (as opposed to ROMANCE NOVEL, WESTERN, etc., all genres which call up different styles of writing, vocabularies, situations, etc.). Frames transform schemas, accounting for the diversity of information we both send and receive — both intended and unintended!

Since they are closely related from a cognitive standpoint, distinguishing the concept of *schema* from that of the *frame* is difficult. One of the differences between the concepts of schema and frame is that schemas may be seen as non-interactive, but frames constantly interact, via *modularity* and *layering*. A situation can be seen not only with reference to discrete, multi-dimensional frames (modularity), but also through these differing frames simultaneously (layering): for example, the letters on this page may be seen as being produced by the intersection of three *modular* key values (**FONT**, **SIZE**, and **STYLE**) *layered* one on the other, to wit:

IDENTITY ALONG DIFFERENT FRAMING DIMENSIONS			
MODULARITY			*LAYERING*
FRAME FONT (COURIER)	FRAME SIZE (12 PT)	FRAME STYLE (SHADOW)	FRAME SIZE + FRAME STYLE
Hog	Hog	**Hog**	**Hog**
How	How	**How**	**How**
Hello	Hello	**Hello**	**Hello**

The distinction between the concepts of *schema* and *frame* can be made clearer from an analysis of an individual letter character. Note that the first letter in each example in the above table ("H") has a deep structure (schema) which can be filled out (instantiated) along many different dimensions (frame).* So, an "H" deep

* [NOTE: those familiar with object-oriented computer programming will see the following description of a schematic deep structure to be identical to what they have previously known as an *algorithm*.]

structure of *two parallel vertical lines of equivalent length X intersected midway by a perpendicular, horizontal line of length X ** n, *[where* n *is a value typically between .33 and .85],* produces something that looks a lot like an "H", but the "H" only gets to us after it has passed through many different stylistic frames (such as FONT, SIZE, STYLE, etc.), as the preceding table clearly shows. But the distinction between schemas and frames is not hard and fast, since the schematic structures we perceive through frames are *themselves* created by the frames we use when we decode reality, thus affecting what we *perceive* as the deep structure, and thus potentially producing pseudo-deep structures: for example, too *specific* a frame decoding the letter "H" produces the *rigid* structure "two parallel one-inch lines intersected midway by a 1/4 inch perpendicular line 1/2 inch up from the base" from a particular example of an "H" which possesses these properties (thus excluding legitimate "H"s which do not fit this rigid description), and too *shallow* a frame decoding "H" produces the *floppy* structure "two lines and a third," (a formulation which calls up many "non-H" geometrical forms). The only structure worthy of being called the *deep* structure is that which captures the *essence* of that which cuts across all instantiated forms, the structure which accounts for all legitimate "H"s, and excludes all those which are not "H." Needless to say, the creation of a deep structure is made far more probable when we see through a *deep decoding frame*.

As we see through frames, so do we communicate with them. Understanding the significance of these interpretive, decoding frames is essential for understanding how human beings see the world. It is also essential for understanding why communication breakdowns are so pervasive. We see what we send as A, while the person who gets what we send sees it as B. *Merely establishing a similar type of encoding does not insure communication.* Frequently miscommunication results when different keys are used in the production and reception of information, a fact vividly displayed with analogies from the field of cryptography. Just agreeing on a "dot and dash" system of communication is not enough; our maps of what the dots and dashes refer to have to correspond, and we have to insure this correspondence before we communicate. When calibration does not proceed communication, we can not be assured that we are referring to the same reality.

This can be illustrated by the following example. Suppose you are confronted with the following string of letters:

ABA

At first glance, you may see this particular string of letters as "nonsense," a function of your use of an interpretive LITERAL frame to decode this string. But suppose you are subsequently told that this string is a "coded message" and that you are to use one of the following keys to decode the message:

String	Key A	Key B
A	M	P
B	O	O

Now you see that to properly interpret this "meaningless" string, you need to shift from a LITERAL interpretive frame to an interpretive frame of CRYPTOGRAPHY, the critical change (because the key for unlocking meaning is provided). Once this major frame shift is made, the only question that remains is *which* key to apply. We note that the application of Key A gives us "MOM," and Key B gives us "POP." Here we can see vividly that sometimes meaning does not reside in the reality itself, but rather in the *keys* used to encode and decode the reality! (To take another example, attorneys, applying their own, private, frame, will have seen the initials to the ***A**merican **B**ar **A**ssociation*). The *same* reality can produce several widely differing meanings with differing keys, or *frames*, as shown by the following examples:

	DECODINGS	
REALITY (Input)	**OBJECTIVE Reading (frame of observable phenomena)**	**SUBJECTIVE Reading (frame of internal reaction)**
She is wearing a watch.	"She is wearing jewelry."	"She is wearing a status symbol."
A car has been behind you for five minutes.	"The car is behind me."	"The car is following me."
A woman smiles at a man.	"She smiled at me."	"She is available."
The price of Apple stock is $37.	"The price of Apple is $37."	"Apple went up $4 today."
Lakers: 110 Clippers: 90	"The Lakers won."	"Magic won in his coaching debut."

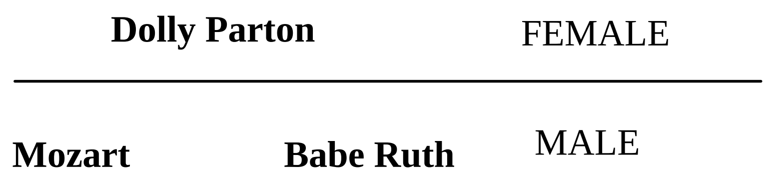
Here we see how different frames of mind produce different interpretations. In a social setting, the problem of frame conflicts becomes acute. Differing frames can produce differing messages in the minds of communicators and listeners, and so communication can silently break down. In the following table, Mr. X wants to send some base messages to Mr. Y, but Mr. X first encodes them within various frames. Mr. Y then uses incorrect decoding frames to interpret, and hears completely different messages:

LITERAL MESSAGE INTENDED BY MR. X	ENCODING FRAME USED BY MR. X TO TRANSMIT THE LITERAL MESSAGE	ACTUAL MESSAGE SENT BY MR. X TO MR. Y AFTER ENCODING	INCORRECT FRAME USED BY MR. Y TO DECODE THE MESSAGE SENT BY MR. X	INCORRECT MESSAGE UNDERSTOOD BY MR. Y AS A RESULT
Jim wants LSD.	**SLANG**	"Get Jim some Vitamin A."	**LITERAL**	"Jim wants Vitamin A. I'll pick some up at the supermarket."
The lab results show I have no trace of cancer.	**MEDICAL**	"The results were *negative*, Mr. X"	**SOCIO-LINGUISTIC**	"I have cancer."
I will give him what he is owed.	**PLEDGE**	"I will give you what you deserve."	**THREAT**	"He is going to do something bad to me."
I'll play a joke.	**APRIL FOOL**	"You're fired."	**LITERAL**	"I'm fired."
He's not going to work here anymore.	**LITERAL**	"You're fired."	**HUMOR**	"He's just kidding."
Inconsistent ideas clash in subconscious.	**METAPHORICAL**	"Colorless green ideas sleep furiously."	**LITERAL**	"That's nonsense."
I escorted her home.	**COLLOQUIAL**	"I saw her home."	**LITERAL**	"He saw her house."
I hated the movie.	**SARCASTIC**	"Best movie I've ever seen."	**LITERAL**	"He loved it."
The girl is not beautiful.	**SARCASTIC**	"She's a beauty."	**METAPHORICAL**	"His car is a beauty."
There is a deep meaning contained in this title, probably having to do with the Latin root *fin* (*end*) and the Irish term "wake". (a *wake* is what you get at the *end* of your life).	**VAGUE**	"Finnegans Wake is an interesting title."	**GRAMMATICAL**	"It's interesting because someone considered a great writer left off the possessive apostrophe. Joyce isn't so great after all."

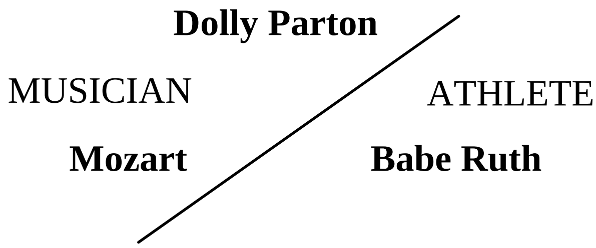
As the preceding table shows, the same language can produce two different meanings depending on which of many possible decoding processes are used. Note that one can correctly decipher a message only when applying the same code both ways. Vocal string "elp-hay ee-may" sends "help me!" to the person who speaks Pig Latin, "blah-blah-blah" to the person who does not. Tone string "dot-dot-dot/dash-dash-dash/dot-dot-dot" sends "SOS" to the person who speaks Morse code, meaningless tones to the person who does not. And a raised dot string sends "Hey there!" to A, a speaker of Braille; B, not a speaker of Braille, comprehends raised dots on a page. Frame analysis reveals that we are in distinct cognitive virtual worlds without even realizing it [since the processes which affect comprehension are invisible, and are only made visible when we act on what we think], and most of the time we are tragically unaware that the person across from us that we are speaking to may be misunderstanding much of what we are talking about!

The above analysis focuses on what is perhaps the key problem for communicators (and thus educators); communication/learning is *encoded* with frames, *communicated* with frames, and *comprehended* with frames, and not only single frames, but sub-frames and sub-sub frames as well, all layered one on the other. Hidden *references* and allusions, differing *modes* of speaking such as literal, metaphorical, hyperbolic, humorous, ironic, academic, and sarcastic, differing *words* such as slang, differing *meanings* for words, vague terms due to *abstraction*, *schemas* necessary for comprehension, the role of *context*, and perhaps most importantly, *deep* and *surface* structures, all play a mutually interactive role in enhancing and interfering with comprehension, and thus can have a profound effect on the subsequent transfer (or lack thereof) of that which has (or has not) been learned.

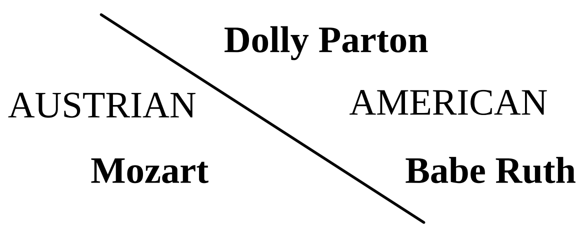
The great power of frames leads to many different comprehension results, by effecting how we *perceive* reality, *categorize* reality, and *evaluate* reality. The outputs in our mind of "same" and "different" and "alien" or "familiar" all take place within the context of how we take in information, a fact which has obvious implications for the theory of "common elements" in transfer. For example, consider the items **Dolly Parton**, **Mozart**, and **Babe Ruth** viewed through the frame of **SEX** :



Within this frame we see Mozart and Babe Ruth as “same” (male), and Dolly Parton as “different” (a female is not a male). In this situation, within this frame, Mozart and Babe Ruth are in the “majority.” But Dolly is only in the “minority” because we have chosen to view reality through that framework. Note the re-ordering when we view through an **OCCUPATIONAL** frame:



Now Dolly is in “the majority.” Are we to conclude from the above that Mozart is always fated to be in the majority? No, since a third result obtains when the items are viewed through a **NATIONALIST** framework:



Here we can see vividly that what counts as “common” is a function of the encoding and decoding framing processes used. The question that remains is, how can these processes be used to facilitate transfer based on a theory of common elements? The answer is to utilize framing techniques to pitch educational concepts at the level that gives the greatest degree of transfer: at the *deep* level.

The Impact of Frame Analysis on the Issue of Transfer

Usage of frame techniques in education is not new: teachers, perhaps since the beginning of civilization, have intuitively used framing techniques for years as a way of achieving educational objectives. Often changing the frame of a situation is just what it takes to do X, whether X is getting a class to be silent, work on an assignment, or become motivated. For example, Teacher A cannot get her first grade children to be silent, until she plays "Simon Says" with the children: it is only when *Simon Says* "be quiet" that the children comply. Teacher B knows that her junior high school students hate math, so she sets up a mock stock market game played with pseudo-dollars; the concepts are paired with money, which the kids are interested in, and they cooperate. Teacher C knows that chess is seen as a "nerd" game in certain subcultures, so when he teaches it he makes sure to use phrases rooted in violence (a concept seen in the subculture as "cool"), to wit, "get him!" "capture him!" "don't let him run away!", etc. Teacher D forms part of his class into "teams" and sets up a "competition" where there are "winners" and "losers." In fact, even when the teacher makes no explicit effort to use framing techniques, framing is nonetheless part and parcel of the daily rituals in educational life; the school itself activates the **THIS IS SCHOOL** frame by displaying flags in classrooms, hanging blackboards on walls, ringing bells every 45 minutes, arranging desks in rows, and by implementing all the other signifiers of the typical educational environment.

A less obvious use of framing, however, is the enhancement of positive transfer. In this regard, the primary use of framing is to get educators to focus in terms of *deep*, as opposed to *surface*, structures. Since transfer occurs only when there are "common elements" in place, it is the role of the teacher to make sure that a) the deep structure of a conceptual subsystem is the target lesson (because significant commonality is at the deep level, not the surface level) and that b) the student is given enough disparate examples to create a deep concept. To take an elementary example of this approach, a teacher should teach the concept of *alliteration* using not only examples from poetry (as is typically done), but also from prose, fiction, and drama. After this initial presentation within the frame of **ENGLISH**, the teacher leaves this primary frame, and gives examples from other, widely disparate frames, such as **MUSIC** (aural), **FILM** (visual), and **HISTORY** (social). So, in **MUSIC**, *alliteration* might be the repetition of a two-note sequence at the beginning of every phrase; in **FILM**, *alliteration* might be the initial presentation of image A from shot to shot (e.g., beginning every shot with a close-up of the star); in **HISTORY**, *alliteration* might be the framing of every different year by beginning with a single event, such as the dropping of a Big Apple in Times Square. The teacher finds these examples, and then teaches them to the students. Taught from so many widely differing areas, the student begins to see the *deep structure* of the concept of *alliteration*, which is **X [letters] X [letters] X [letters]**. In this situation, positive transfer (the ability to discern an alliterative situation in *any* domain) is made far more probable.

The use of many examples from a variety of different domains has been referred to by Butterfield, Slocum, and Nelson (1993) as the use of *generative frames*: pitching the level of learning at the conceptual level. According to the authors, all deep conceptual learning is generative because it allows the learner to correctly classify examples never seen before, from *simple* (e.g., a person seeing a new tree could nevertheless identify it as a tree) to *complex* (e.g. the generative frame "when you know what to do with one example of a concept, you can do it with other examples" can be applied by a person to many different examples). Properly used, examples can exemplify deep structures.

As Haring (1985) found, the teaching of even simple concepts requires a minimum of several examples, and thus it is not surprising that studies attempting to promote the use of generative frames by providing only a single example usually fail (e.g., Gick & Holyoak, 1980; Reed, Ernst, & Banerji, 1974) since a single example can be seen in terms of any one of hundreds of concepts (e.g., “Mozart” = MAN, MUSICIAN, DEAD, AUSTRIAN, DIED YOUNG, SUBJECT OF MOVIE, MARRIED, etc.), thus providing no basis for learning a single frame/concept, nor any basis for generalization with reference to aspect X. Studies that *have* included more than one example have found the use of learned frames on new analogous instances (e.g., Butterfield & Nelson, 1991; Gick & Holyoak, 1983). In fact, generalization by intersection (finding common components) is a technique frequently used in artificial intelligence programs that learn (Winston, 1975). Once a concept has been acquired, transfer results simply from applying the concept to new cases, from whatever domain, that exemplify the concept.

These insights have important implications not only for the *enhancement of positive transfer*, but also the *prevention of negative transfer*. The **DEEP STRUCTURE** frame helps combat a latent defect of the mind, which is an overreliance on surface data to key in problem-solving processes.

As Keane (1988) noted, superficially-similar situations tend to be retrieved rather than deep structures because more vivid surface features frequently activate *irrelevant* analogues, and in so doing block the retrieval of *relevant* analogues such as deep structures. Consider how this cognitive defect can effect student resolution of the following three example problems (Reed, 1993, at p. 62):

Joe had three marbles. Then Tom gave him five more marbles. How many marbles does Joe have now?

Joe has three marbles. Tom has five marbles. How many marbles do they have together?

Joe has three marbles. Tom has five more marbles than Joe. How many marbles does Tom have?

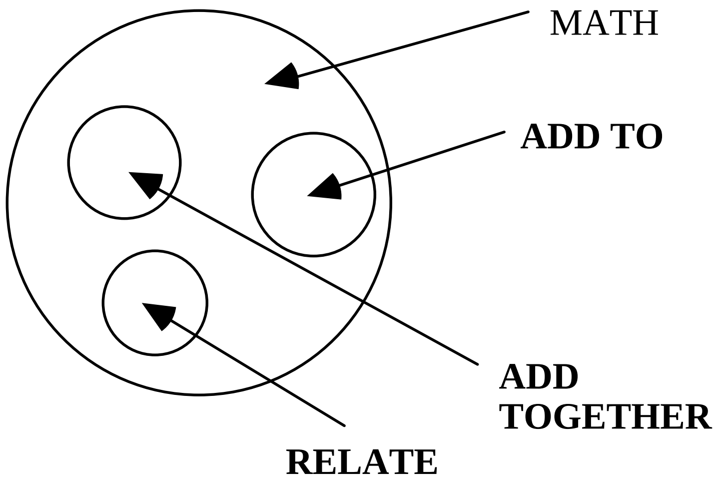
Here the *similar surfaces* of these three situations (three sentences, "marbles," "Tom," "Joe," "how many . . . have") can interfere with the perception that these are three *different* kinds of problems which require three very different processes for their solution:

	PROCEDURE	EFFECT ON A	EFFECT ON QUANTITY
ADD TO	***add x to A***	A changes	*no* new quantity
ADD TOGETHER	***add A and B to get C***	A *does not* change	new quantity
RELATE	***relate A to B to discover B***	A *does not* change	*no* new quantity

A student untrained at the deep level would perhaps, after having learned the process for the *add to* problem, erroneously apply that process to an *add together* problem because the surface features of the problem were identical (a sterling case of negative transfer). Training in the deep structure is necessary to prevent the student from inappropriately generalizing or failing to generalize, getting frustrated, and perhaps even erroneously concluding that he or she is "stupid." It is also essential for teaching perhaps the most important cognitive skill: *critical thinking*.

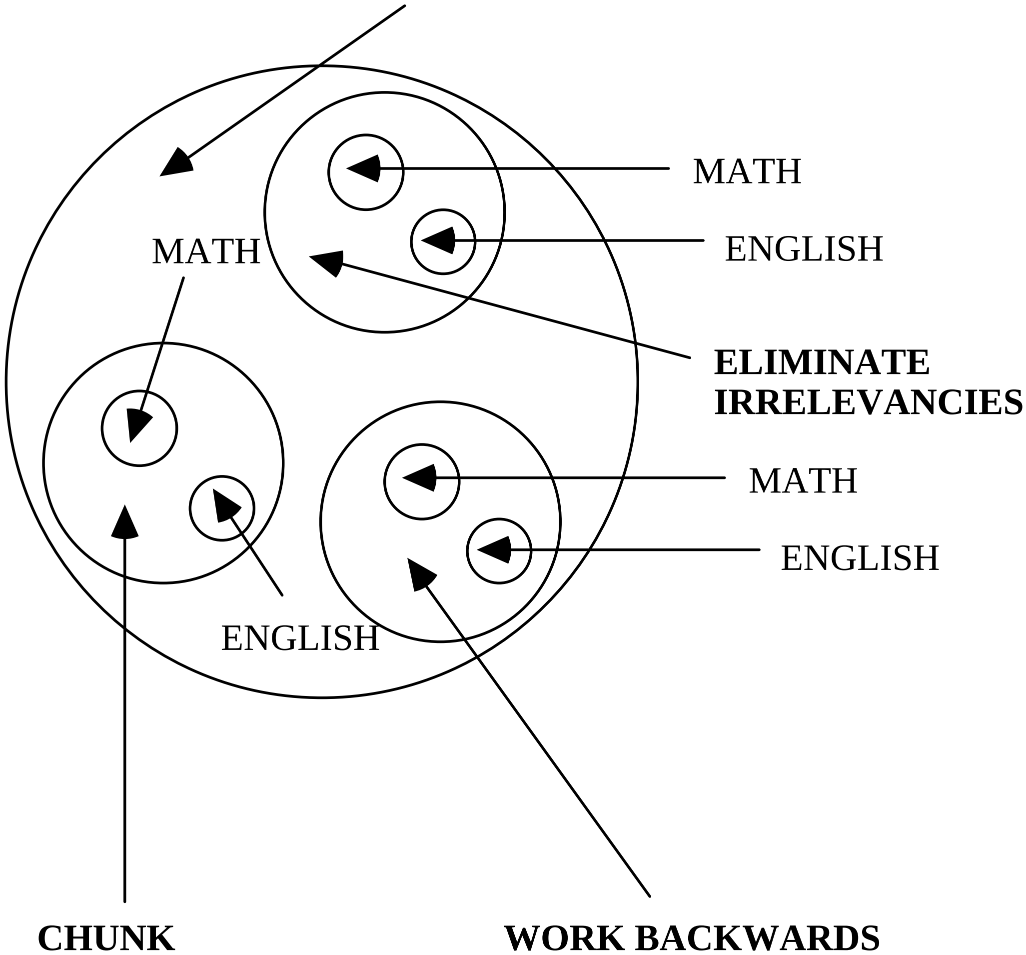
Transfer, Frame Analysis, and the Teaching of Critical Thinking

Framing education at the deep level can not only enhance positive transfer, and help to combat negative transfer, but the basic approach guarantees that the student will be put into a *critical thinking* mode, as opposed to the current declarative knowledge mode, which is focused on the memorization of facts divorced from their contexts. It could even be plausibly argued that without a radical re-framing of *education within domains* to *education across domains*, much of the applicability of critical thinking (its application to *any* domain) will be lost. To see the notion of domain specificity, note that the previously referred-to Joe/Tom math problems are typically discussed within a **MATH** frame:



Thus, if the student is in math class, and is given the Joe/Tom problems, at least one of the above procedures will occur to the student ("Okay, I'm in math class now. Solving these problems will involve either *add to*, *add together*, or *relate*, and not *make past tense*, *interpret metaphorical as literal*, etc."). The surface features of math problems typically call up **MATH** frames, but critical thinking transfer will only be taught when these features call up problem-solving **HEURISTIC** *frames* created by an education system which has previously subcategorized declarative knowledge under procedural (as opposed to the reverse, the status quo), as follows:

PROBLEM-SOLVING (HEURISTICS)



When declarative knowledge is subsumed under the rubric of procedural knowledge, problem-solving (heuristic) techniques will be *taught across declarative knowledge domains*, such as **MATH** and **ENGLISH**. Unfortunately, current education parcels out the day in terms of declarative knowledge units ("a noun is a person, place or thing"; "Albany is the capital of New York") typically associated with their subject fields, thus permanently anchoring knowledge in terms of local solutions (problem-solving modes confined to the specific field of inquiry), and reducing the probability of positive transfer. Unfortunately, local framing teaches local processes: thus, *addition* is a process *only* to be applied in **MATH**, and *make past tense* is a process *only* to be applied in **ENGLISH**. Since *make past tense* may not properly be applied to numbers, which exist in ideological and not temporal spheres, the **ENGLISH** algorithm *make past tense* is domain-specific and non-transferable, and the teaching of a number of these kinds of algorithms can lead a student (and teacher) to the conclusion that "transfer is not possible." Yet heuristic processes such as *eliminate irrelevancies* do not labor under this handicap. For example, one can *eliminate irrelevant data* in paragraphs (**ENGLISH**), and one can *eliminate irrelevant data* in word problems (**MATH**). *Eliminate irrelevancies* is a global skill that, when practiced in **MATH**, will enhance the ability to solve the same problem in **ENGLISH**. Consider the *Socks Problem* (Sternberg, 1987 at p. 207):

> **Suppose you have brown socks and blue socks in a drawer, mixed in a ratio of 4 to 5. What is the maximum number of socks you have to take out of the drawer to be assured of having a pair of socks of the same color?**

Those able to solve this problem know that the 4-to-5 ratio given in the problem is *irrelevant.* Solving this problem in **MATH** by finding an irrelevancy will strengthen the ability to solve the same problem in **ENGLISH** (finding an irrelevancy), because the concept has been strengthened by yet another example. Seeing irrelevance at the deep level will strengthen the concept of *irrelevance*, and thus aid in the solution of those other problems in life whose resolution requires finding the signal in the noise.

Similarly, *working backwards* is a valuable problem-solving skill. Seeing a situation in terms of BEGINNING and ENDING by starting from a known helps the student find the syntax of a situation (which aids in the situation's resolution). In **MATH**, for example, the solution of the addition problem

S E N D *plus*
M O R E *equals*
M O N E Y

requires a reversal of typical math syntax, since one must work from the only *known*, which is that the M in "money" must be the number "1," (since "1" is the only possible answer); thus, the problem has to be worked from left-to-right, *backwards*, as opposed to the typical right-to-left syntax schema called up in solving math problems. (*See* Bartlett, 1958). When this process is also taught in **ENGLISH** (e.g., one can make writing easier by using the heuristic of *working backwards* by figuring out the end of a story first and then figuring out the characters, plot and setting required to get to the ending), the student has begun to see the abstract, deep side of backwards motion.

Chunk is another useful heuristic that easily transfers across domains. Different ways of chunking produce different outputs: for example, in **ENGLISH** the output can be "same" and "different" (which affects the way we categorize, organize, think, and write), while in **MATH** the output can be two different arithmetic results. Thus in **ENGLISH** *chunk* will allow us to see that "Dolly Parton" and "Mozart" are similar to each other and different from "Babe Ruth" only with reference to a certain category frame (**OCCUPATION**), while in **MATH** we find that we only get *20* from 4 * 3 + 2 when we chunk as **4** * **(3 + 2)**, and not **(4 + 3)** * **2**, which produces *14*. Different chunking leads to different outputs, in **MATH** and **ENGLISH**!

But the above heuristics are only a small set of the hundreds of essential problem-solving skills people need to resolve difficult situations. The following is brief list of heuristics that can cut across widely different domains:

WORK BACKWARDS	**CHUNK**	**ELIMINATE IRRELEVANCIES**	**MAP**
DELETE	**COMBINE**	**DECREMENT**	**FIND EXAMPLES**
FOCUS	**GO BACK**	**SKIP**	**SCHEMATIZE**
DEFINE TERMS	**GATHER**	**SCAFFOLD**	**PRIORITIZE**
OVERSAMPLE	**REDUCE TEMPO**	**INCREMENT**	**MODULARIZE**
SORT	**MEASURE PROGRESS**	**INCREASE SORT KEYS**	**BINARY SEARCH**
FIND AN ANALOGOUS SOLVED PROBLEM	**ISOLATE PARAMETERS**	**FIND THE SYNTAX OF THE SITUATION**	**SEEK EFFICIENCY**
TEST COUNTERFACTUALS	**SHIFT THE REFERENCE FRAME**	**MAKE VARIABLES**	**SOLVE A SIMPLER PROBLEM**

Education organized in terms of global heuristic skills can transfer across what are on the surface very dissimilar declarative knowledge domains, because identity will exist in the deep structure of the frames used to transmit these heuristic skills.

If a school is organized in terms of heuristics, courses will change from those conveying declarative knowledge to those involving knowledge of problem-solving processes. Here is a sample course content:

Critical Thinking

- *Heuristics*
  - Math
  - English
  - Science
- *General Semantics*
  - Frame Analysis
  - Interpretation
- *Subroutinization of Thought*
  - Chess
  - Programming
- *Scientific Method*
  - Statistics
  - Hypothesis testing

A student graduated from this school, a school which has radically re-framed the educational day so as to greatly increase the probability of positive transfer, would be a student who would see every problematic situation as one which could be dealt with by applying the proper approach.

The ability to see in terms of deep structures, an artifact of an educational approach rooted in deep-structure analysis, will enable the student to be the master of his or her own perception. No longer the captive of whatever local frames are called up by surface features, the student will be able to get *many* kinds of information from the same text (seeing all the inherent possibilities), and *one* kind of information from many different texts (seeing the forest, not the trees). Education will be efficient because each problem-solving situation will be a rehearsal for the next problem-solving situation. The liberation from old tricks taught by old dogs within old frames will help all of us trying to cope with an endlessly morphing, Third Millennium world.

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