FACT FINDING

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VALUE PROGRAMS

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INTRODUCTION

Every problem is surrounded by information that is fundamental to the development of a solution. Much of this information, however, is bypassed by our tendency to preconcieve our own views of facts and to reject the data that doesn't support our assumptions. As a result, we often end up with a solution to a problem that would have been different if we had checked out the validity of our assumptions or had asked the "obvious" first question. Most problems have obvious facts that can be gathered. A proficiency in problem sensitivity, supported by a high level of objectivity, greatly influences the quality and structure of information that is searched. Werthiemer made the following observation on the importance of fact finding:

> *The function of thinking is not just solving an actual problem, but discovering, envisaging, going into deeper questions. Often in great discoveries the most important thing is that a certain question is found. Envisaging and putting the productive question is often more important, often a greater achievement than solution of a set question.*[1]

PROBLEM SET MATRIX

Issues needing to be resolved can consist of two elements: the problem and the solution. From these two elements, four problem sets can be identified by considering whether the problem and/or the solution is known or unknown. (See Figure 1.)

PROBLEM	UNKNOWN	SET 2 APPLICATIONS	SET 4 INVESTIGATION
	KNOWN	SET 1 SPECIFIC VALUES	SET 3 REQUIREMENTS
		KNOWN	UNKNOWN
		SOLUTION	

Problem Set Matrix *Figure 1*

[1] Wertheimer, M., *Productive Thinking,* NYC: Harper, 1959.

1. *Problem is known and solution is known.* This problem set describes an analytical problem that can be solved by a known equation. Known values are determined and applied to the equation to arrive at the solution. As an example, determining the gas consumption rate of an automobile requires calculating the amount of gasoline consumed in traveling a certain specific distance. The solution is arrived at by dividing the distance traveled by the amount of gasoline consumed — miles per gallon. The solution is known, but the quantitative values must be determined.

2. *Problem is unknown and solution is known.* This problem set is a solution in search of a problem. This type of problem is common to sales personnel whose product or service represents a solution and who search for additional problems or "opportunities" that can be solved with the use of the product or service. Another situation is where monies are available and the search is for the problem that could best benefit from the funds. This problem set also describes the process of basic research that seeks a problem that can utilize a scientific fact. For example, the laser's application to ophthalmic surgery was created after the laser was developed.

3. *Problem is known and solution is unknown.* In this quadrant the problem is well-defined by requirements, specifications, and other restrictive parameters. The solution to this problem set requires developing a way to satisfy the conditions. Designing a product to meet specifications is a typical problem within this problem set.

4. *Problem is unknown and solution is unknown.* A problem in this quadrant cannot be solved. The problem set requires an investigation that will define the problem and move it into Problem Set 3 where the problem is known and the solution is unknown. Typical problem statements for this set are: How can the needs of the market be met? How can the effects of energy shortages on factories be reduced? The problems placed in this set require more fact finding effort to define and scope the problem and make it "known", i.e., determine the needs and effects.

Each of these problem sets, as shown in Figure 1, requires a different type of fact finding. The matrix provides a frame work for determining the type of information needed and the opportunity available for creativity for various problem sets. In the problem set matrix, the need for creativity in developing a solution increases as the problem advances from left to right, and the need for creativity in defining the problem increases as the problem advances from bottom to top. Set 4, as example, requires creativity for both the problem and the solution, whereas Set 3 requires creativity only for the solution, since the problem is already defined. Problems do not always fall clearly into one set. Some elements of a problem may be known and some unknown. The unknown elements require identification and investigation so the unknowns become known.

In *Problem Identification,* the emphasis is on identifying and structuring the problem through an analysis of the function or what we are trying to accomplish by a solution. Most of the constraints that our solution must satisfy will be expressed as requirements.

However, cost is an additional consideration that is involved in evaluating most problems. Although cost is not a function, it greatly influences the solution options. Fact finding and information gathering will consider cost as well as function requirements.

The data that is required will essentially fall into four categories and will answer the following questions:

What functions are currently being performed?
What do they cost?
What functions are actually required?
What should they cost?

The data generated from the first two questions are used to further clarify the problem. The data from the last two questions are used to establish the conditions desired of the solution. For those problems where there is no existing condition, the first two questions will not be applicable. However, it is often helpful to assume a solution (a similar object or procedure) as a baseline to use as a point of departure.

FUNCTION REQUIREMENTS

In the monograph, *Problem Identification,* a problem is structured and a number of functions identified. Each function presents an opportunity to search for a better means of achieving a solution. In order to evaluate the options, there must be requirements against which a judgement is made. For each function identified, information should be obtained that will further clarify the problem. From this information, requirements are developed for evaluating the various options.

Problem solving involves systematically investigating the variety of functions identified in a problem structure to arrive at the best way of satisfying those functions. This systematic investigation starts at the high order functions and progresses down (right) through the lower order functions. The level where the problem is bounded by scope lines identifies the basic function for that investigation. The basic function, by definition, is the first function to the right of the left scope line. Once defined, basic functions do not change. Using a FAST diagram for a cigarette lighter, Figure 2 illustrates two arbitrary positions of the left scope line and the type of specifications that might be required as the respective functions become basic.

FAST DIAGRAM
TOBACCO LIGHTER
(CIGARETTE LIGHTER - FLUID FILLED)

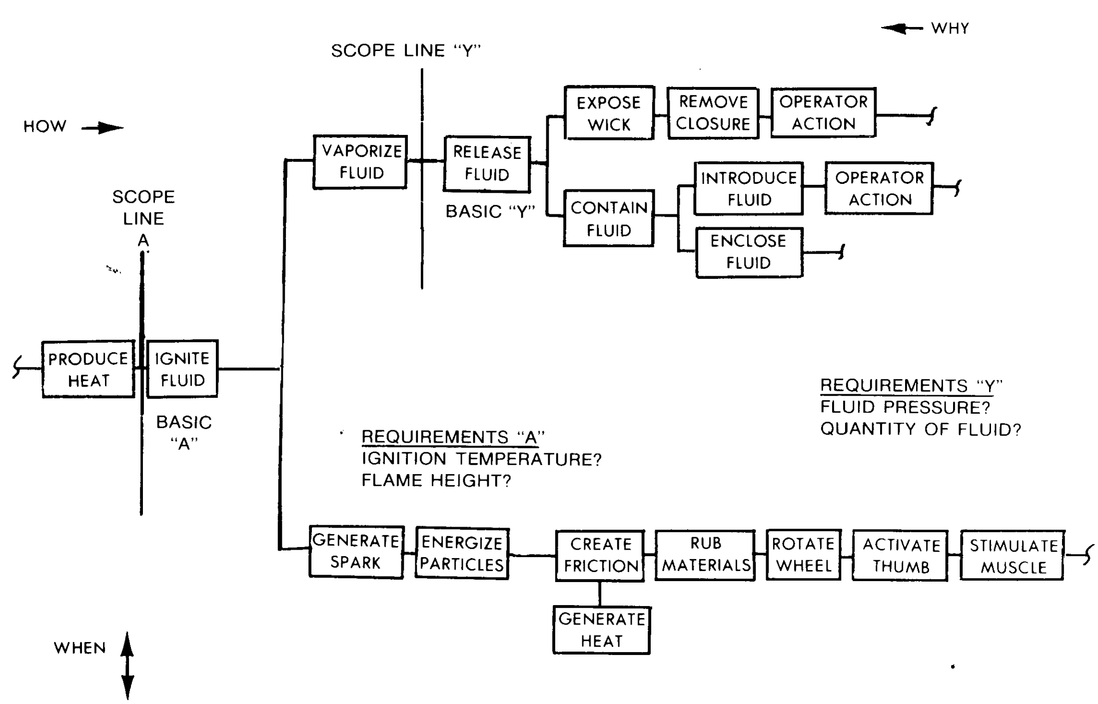


Figure 2

The solution of "ignite fluid" (reference scope line "A") may result in a battery ignited lighter which would change all the subsequent functions in the "how" direction and their requirements, particularly the "generate spark" function and its dependent functions. As elements of the problem are resolved and the scope line moves to the right, there may be additional modifications to the initial FAST diagram. The requirements at scope line "Y" may vary, depending on whether the fluid is liquid or butane gas. As an example, a gas lighter does not require the function "expose wick". However, when we are investigating the problem at scope line "Y", the nature of the fluid and its requirements will have been previously determined.

Regardless of the structure used for identifying the problem, the requirements at the level of the investigation must be identified. It is important not to assign lower level requirements to higher level functions. This will cause the presumption of a solution.

Frequently the information gathered during fact finding is so revealing that the problem is virtually self-solving. The following is an example of a solution emerging after fact finding.

A student of creative problem solving wanted to practice his creative abilities on a home problem. He noticed his wife would remove about 3 inches from the small end of a ham before baking. His problem sensitivity alerted him to investigate why the end was cut off. His wife didn't know; that was how her mother had taught her. A subsequent visit with her mother disclosed that she didn't know either and that her mother taught her to remove the end. The grandmother was then contacted to find out if she knew why the end was cut off. "Sure," she said, "I didn't have a large enough roaster to take a whole ham!"

Fact finding can also cause a redefinition or restructuring of the problem. Problem identification and fact finding is a repetitive process inasmuch as we cycle from one to the other to refine and define the problem. The following is an actual example of how this cycling process led to a self-solving problem.

A value engineering task team was convened to study a proposed multimillion dollar chemical facility. One area identified as a value engineering opportunity was a proposed single story building estimated to cost $1,200,000. The V.E. team defined the basic function of the building as "control environment". In the fact finding phase, the team sought information to determine for whom or what this environment was being controlled. They discovered that personnel would not be working in the building. The structure was designed to contain large compressor-type equipment. Personnel would periodically record data from the equipment but would not reside in the building.

It was further learned from the manufacturer that the equipment was designed to be weather resistant. It was concluded that the basic function selected was improper since the building did not have to provide a "controlled environment" for personnel or equipment. The basic function was then reidentified as "support crane". The building design supported an overhead crane to disassemble and move the equipment to a maintenance facility for repair. During the fact finding, it was found that the size and weight of the equipment could be handled by a mobile crane. However, the crane could not enter the building. Since the mobile crane satisfied the function without the building, it was determined the building was not only superfluous but restricted crane access. The building was deleted from the plans for a savings of $1,200,000.

Not all problems fall apart this easily. However, if the problem had not been structured to provide visibility and understanding of the basic functions, the proper questions and information might not have been generated. In this problem, the basic function was challenged. Asking the "obvious" first question often leads to the true nature of the basic function.

Too often the functions and requirements are left unchallenged and are accepted as being valid. We are not always aware of the constraints we impose on the problem. We accept the habits of the past as valid requirements; we accept, as facts, our perception of what the boss or customer needs; we accept our knowledge as the only resource available for solution.

The way information is extracted and presented also has a bearing on how it is used. Failure to confirm the "obvious" tends to support assumptions that have no basis of fact, yet they are accepted as the "unsaid truth".

A task team was charged with structuring the best function/cost balance to build a higher bridge that would replace the existing drawbridge. The answer to why the bridge needed replacement when it had 15 to 20 years additional life was, "Ships keep hitting the bridge. Last year we spent over $300,000 in repairs alone."

Ordinarily, this would be a rational justification for the project. But then someone asked an "obvious" question: "But why are the ships hitting the bridge?" The answer: "Because the bridge handler could not hear the boat whistle, and the ships, rounding the bends on either side, could not stop in time."

The solution recommended was NOT a new bridge, but a better method for warning of oncoming ships.

COST REQUIREMENTS

Sooner or later someone has to foot the bill to develop and implement our ideas. It may be ourselves, our company or our customers. Cost is a universal common denominator in the final evaluation of almost every solution. If candidate solutions were evaluated based only on meeting function requirements, the solution selected may be too costly to implement or price us out of the market. After ideas are generated, they will be subjected to a cost analysis as well as a function analysis to select the idea that best satisfies both requirements.

The collection of cost data is initiated at this time in order to give visibility to those areas where existing costs are excessive and to establish cost targets for the subsequent evaluation of candidate solutions. An indepth coverage for establishing cost targets is contained in the monograph, *Design-to-Cost (DTC)*. The emphasis here is on cost data that may disclose additional or potential problem areas. As in the function requirements, if a current solution does not exist, then the current cost data does not exist.

Methods of giving visibility to cost data to identify cost problems are as varied as the types of problems. There are three general approaches that are frequently used and can be creatively modified for specific applications.

Function/Cost Relation. The problem structure in the monograph, *Problem Identification,* is a display of the functions that are to be satisfied by a solution. By allocating the cost of components, process steps, or operations to the various contributing functions will result in developing the costs per function. Figure 3 is an example of how the component costs of a light switch were allocated to the function they performed.

COMPONENTS		FUNCTION													
		SUPPORT SWITCH		TRANSMIT MOTION		MAKE/BREAK CIRCUIT		INSULATE CURRENT		CONDUCT CURRENT		ENCLOSE COMPONENTS		ATTACH COMPONENTS	
	COST	%	COST	%	COST	%	COST	%	COST	%	COST	%	COST	%	COST
		TOGGLE SWITCH													
FACE PLATE	.06	100	.06												
TOGGLE RETAINER	.04	50	.02	50	.02										
TOGGLE	.03			100	.03										
SWIVEL	.02			100	.02										
SPRING	.01					100	.01								
CONTACT ASS'Y	.06					50	.03			50	.03				
INSULATOR	.02							100	.02						
TERMINAL	.04									100	.04				
HOUSING	.04	25	.01									50	.02	25	.01
SCREW	.02													100	.02
TOTAL	.34	26	.09	20	.07	12	.04	6	.02	21	.07	6	.02	9	.03

Figure 3

Although this data is shown in matrix form, it could also be posted on a hierarchical or FAST diagram. The purpose of the data is to highlight areas where cost is a *part* of the problem or *is* the problem. In the above matrix, it should be noted that the lesser functions of "support switch" and "transmit motion" account for 46% of the cost of the switch. This would generally indicate an area where it is costing too much to perform these lesser, secondary functions.

Cost per Characteristic. When shopping, we often make judgements on the basis of a cost per characteristic. We might purchase an item based on the cost per gallon, cost per pound or cost per foot. These are broad measures we often use to give visibility of one product or service compared with another. This method of comparison can be applied to specific characteristics of the problem. In a study of processing a purchase requisition, for example, the cost per requisition, cost per dollar value ordered, and cost per quantity of items ordered could all be determined depending on what is significant to the problem under study. The characteristics that can be compared are determined by the problem and the imagination of the problem solver.

Some of the common quantitative characteristics are:

cost per: Weight
Length
Area
Volume
Horsepower
Watt
Lumen
Volt
Ampere
Torque
Time
Cycles
Resistance
Temperature
Pressure

Incremental Cost. When an item is being processed through several stages of operation, costs are incurred at each step. This applies to a requisition being processed in an office, or hardware being machined in a shop. A detailed look at how these costs build up can focus in on a particular operation that may be causing a cost problem. Figure 4 illustrates a part that is being processed in a machine shop through various operations. By looking at the cost per characteristic (cost per pound in this case), we can see the milling operation more than doubles the cost per pound and may be an area that should be specifically studied.

INCREMENTAL COST

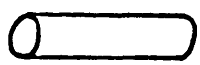
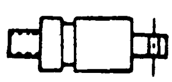
OPERATION	WT. (LBS.)	MAT'L/ LABOR COST	CUMULA-TIVE COST	COST/ LB.
MAT'L 	1.00	.15	.15	.15
TURN 	.75	.50	.65	.87
DRILL 	.70	.25	.90	1.28
MILL 	.55	.75	1.65	3.00
HEAT TREAT	.55	.75	1.80	3.27
PLATE	.55	.10	1.30	3.45

Figure 4

There are various ways that cost can be used to further identify the problem. The function/cost relation can be applied to any problem structure. The other techniques, and those of your own invention, should be used to extract meaningful information from data to highlight problem areas.

DATA COLLECTION

Defining the requirements for the basic function and each of the lower order functions permits an organized approach for fact finding. During fact finding we are attempting to answer the questions:

— What is it that I need to know?

— Where might this information be available?

— What am I assuming that may not be valid?

These questions can be used in a brainstorming session to surface all the items that we might need to know and then screen down to those items that are the most significant for the problem. Obtaining this information can be approached in the same manner. Identifying the data to be collected and where it can be found requires the use of fluency and flexibility as described in the monograph, *Creative Traits*.

A convenient form for posting questions, sources and answers is included in Appendix A. It is important to record all the information collected so it can be referred to later, during the evaluation of ideas. The use of the data at this time is to assure the problem is properly defined and there aren't omissions in the problem.

The following checklist will assist in determining whether the information that has been gathered should be further screened, challenged, or accepted.

a. Does the information suggest a redefinition of the problem?
b. Is the information valid for the problem under study?
c. Is the information current?
d. Do the various information items support each other or are they in conflict?
e. If the information is contrary to your initial perception, are the conflicts resolved to your satisfaction?
f. Are there information items that you do not trust as being accurate or representative?
g. Are there relationships or associations between various information items that should be explored further?
h. Do you suspect a behavioral bias in the information?
i. If any information items appears to impose a severe constraint on potential solutions, has it been verified by more than one source?

COMPLETENESS OF INFORMATION

It is impossible to gather all the facts or information concerning a specific problem. A highly creative person can tolerate the ambiguous condition of not having all the information available. His problem sensitivity will tend to guide him toward the information that is pertinent and avoid the nonrelevant information. Valid conclusions can often be derived from the incomplete but relevant information, but non-relevant information does not permit valid conclusions. The following illustrates half the information of a famous writing — the nonrelevant half.

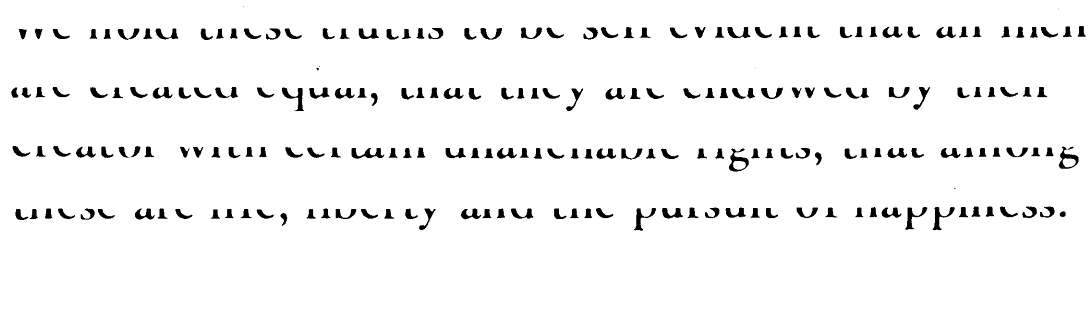


Figure 5

The following is the relevant half of the same passage.

> We hold these truths to be self-evident that all men are created equal that they are endowed by their creator with certain unalienable rights that among these are life liberty and the pursuit of happiness[2]

Figure 6

With the correct half, we can often make valid assumptions about the missing parts. We aren't always sure that we have sufficient information or that the information fits together. There are several exercises in Appendices B and C that will test your ability to manipulate information in order to resolve a problem.

CREDITABLE INFORMATION SOURCES

Whether fact finding is accomplished through interviews, extracted from reference material, or obtained through experiment, objectivity must be maintained. If the data is distorted, the solution will be distorted. Very often we interpret information the way we think it should be and not the way it actually is. To test your bias, read the statements within the triangles.

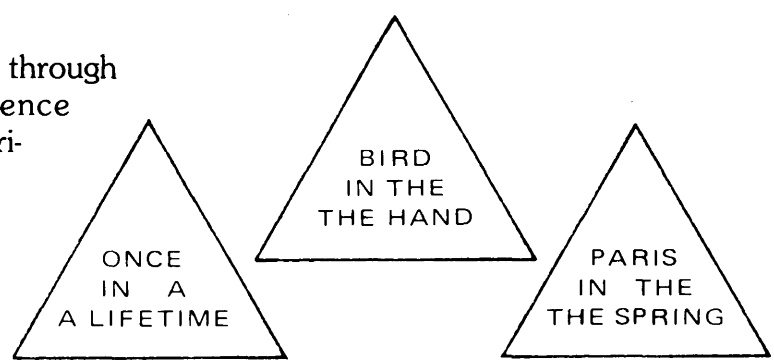


Figure 7

Did you notice anything unusual about the statements? Most people will read these as very familiar statements without noticing that the third word is repeated. Often we are so sure of what the information says that we really don't read it. We not only have our own creditability to be alert to, but also that of the suppliers of the information. Although we cannot verify all data, we can improve the probability of it being accurate and responsive by using sources of known high creditability.

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[2] U.S. Department of Health, Education & Welfare, *How to See,* DHEW Publication (SSA) 73-10063, 1973.

DATA DISPLAY

Often the data, as collected, will not be meaningful without further manipulation or display. The data may be in bits and pieces much like in "Who Owns the Zebra? (Appendix B)

The method of displaying data is often as important as the data itself. Until meaningful information can be extracted from the data, it tends to be a source of frustration and just gets in the way. There are many ways of displaying data and they should be approached creatively in order to give visibility to the information desired. Common display forms are:

Tabulations —	Compare data on one list with that of another.
Matrix or Morphological —	Evaluate or compare the relationship of one set of data items with another.
Chart or graph —	Shows trend of data or comparison of data.
Percent or ratio —	Divide one data value by another to show a relationship.

Fact finding is the phase where we identify the information concerning the problem and eliminate the invalid assumptions. This information is converted to requirements and the individual requirements are assigned to the applicable functions. The information gathered, including cost data, must be structured and displayed in order to give meaningful form to the data. The information is used to clarify the problem and will be used later for evaluating candidate solutions.

APPENDICES

A. Fact Finding Form

B. Information Problem:
Who Owns the Zebra?

C. Information Problem:
Protocol Analysis.

FACT FINDING

Problem Statement ____

Facts or information required	Possible Sources for Answer	Priority	Summary of information obtained (list person's name, report title, or any other source of information)
	1. ______ 2. ______ 3. ______ 4. ______ 5. ______	______ ______ ______ ______ ______	
	1. ______ 2. ______ 3. ______ 4. ______ 5. ______	______ ______ ______ ______ ______	
	1. ______ 2. ______ 3. ______ 4. ______ 5. ______	______ ______ ______ ______ ______	
	1. ______ 2. ______ 3. ______ 4. ______ 5. ______	______ ______ ______ ______ ______	

This example illustrates the harvesting of seemingly unrelated facts which, when analyzed properly, result in the solution sought.

WHO OWNS THE ZEBRA?

1. There are five houses, each of a different color and inhabited by men of different nationalities, with different pets, drinks, and cigarettes.

2. The Englishman lives in the red house.

3. The Spaniard owns the dog.

4. Coffee is drunk in the green house.

5. The Ukrainian drinks tea.

6. The green house is immediately to the right (your right) of the ivory house.

7. The Old Gold smoker owns snails.

8. Kools are smoked in the yellow house.

9. Milk is drunk in the middle house.

10. The Norwegian lives in the first house on the left.

11. The man who smokes Chesterfields lives in the house next to the man with the fox.

12. Kools are smoked in the house next to the house where the horse is kept.

13. The Lucky Strike smoker drinks orange juice.

14. The Japanese smokes Parliaments.

15. The Norwegian lives next to the blue house.

Now, who drinks water? And who owns the zebra?

Do not turn page for answers until the solution has been attempted.

ANSWERS TO "WHO OWNS THE ZEBRA?"

The Norwegian drinks water; the Japanese owns the zebra.

HOUSES:	Yellow	Blue	Red	Ivory	Green
INHABITANTS:	Norwegian	Ukrainian	Englishman	Spaniard	Japanese
PETS:	Fox	Horse	Snails	Dog	Zebra
BEVERAGES:	Water	Tea	Milk	O.J.	Coffee
CIGARETTES:	Kools	Chesterfield	Old Golds	Lucky Strike	Parliament

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Protocol Analysis in Creative Problem-Solving (an excerpt)

Problem

A conversation took place between two friends, a philosopher and a mathematician, who had not seen or heard from one another in years. The mathematician, who had an exceedingly good memory, asked the philosopher how many children he had. The philosopher replied that he had three. The mathematician then asked how old the children were. His friend, who knew how much most mathematicians enjoy puzzles, said he would give him a number of clues to his children's ages. The philosopher's first clue: "The product of the children's ages is 36." The mathematician immediately replied that this was insufficient information. The philosopher's second clue: "All of the children's ages are integers; none are fractional ages, e.g., 1½ years old." Still, the mathematician could not deduce the correct answer. The philosopher's third clue: "The sum of the three children's ages is identical to the address of the house where we played chess together often, years ago." The mathematician still required more information. The philosopher then gave his fourth clue: "The oldest child looks like me." At this point, the mathematician was able to determine the ages of the three children. This is the problem: What were their ages, and what was the mathematician's reasoning?

Protocol

What information do I have? (1) There are three children. (2) The product of their ages is 36. (3) All their ages are integers. (4) The sum of their ages is identical to the address of a house where the two friends used to play chess together frequently. (5) The oldest child looks like the philosopher. Anything else? Yes, (6) the mathematician is endowed with a very fine memory. Anything more? Yes, (7) only when he possessed all of the information (1) - (5) could the mathematician deduce the children's ages.

Now I will try to work with these clues to see if I can reach a conclusion as the mathematician did. I have the data, (1)-(7) above, before me. Some of these pieces of information make sense, e.g., (1), (2), (3), and (7); but (4) and (5) don't help me very much — unlike the mathematician with his good memory (6), I don't know the address of the house where the two friends used to play chess, and I can't see how (5) helps at all.

Do not read on until you determine how to approach the use of the information.

Well, I'll try to work with the information I can understand and hope the rest falls into place gradually . . . Let me see, there are three children, their ages when multiplied together equal 36, and none are fractions. What possible combinations of ages satisfy these conditions?

There seem to be eight combinations; I believe I have exhausted them all, since I rechecked my list several times carefully:

a. 1 x 1 x 36
b. 1 x 2 x 18
c. 1 x 3 x 12
d. 1 x 4 x 9
e. 1 x 6 x 6
f. 2 x 2 x 9
g. 2 x 3 x 6
h. 3 x 3 x 4

Now let me add up the ages in each of the above combinations to see what the sums look like:

a. 38	e. 13
b. 21	f. 13
c. 16	g. 11
d. 14	h. 10

What have I done so far? I have listed the different combinations of three ages which when multiplied together lead to a product of 36. I have included only ages that are integers. And I have added up these combinations of ages and now have eight totals, ranging from 10 to 38.

Since I know the mathematician has an exceedingly good memory, he should of course know what the address was of the house in which he and his philosopher friend played chess frequently. However, he was unable to determine which of the eight cases above was the correct one, even with this information. He needed yet another clue from the philosopher, the fourth clue. Why would he need more information as he did?

Do not read on until an attempt has been made to obtain an answer from the information now available.

As I look over the eight totals above, I see that two of them, e. and f., are both 13. Only in these two cases would the mathematician remain uncertain, since otherwise his exceedingly good memory would enable him to identify the number identical to the address of the house where the two friends use to play chess together. Since he remained uncertain at this point, his uncertainty must have been due to this fact that the sums of both combinations e. and f. were correct, yet there was no way as yet to decide between them.

The philosopher's fourth and last clue did, however, enable the mathematician to deduce the children's ages. What was that clue again? It was, "the oldest child looks like me." What information is contained in this clue? Well first of all, that there is a child who is the eldest of the three and that this child looks like the philosopher. So we know one of the three children must be older than the other two. And this enables me, along with the mathematician, to choose between combinations e. and f., since only in combination f., in which the children's ages are 2, 2, and 9, is an *oldest* child. This, then, must be the answer and this must have been the mathematician's reasoning.

Analysis of Protocol

First, I tried to summarize what information the problem contained. Some of this information made good sense to me, some didn't. I decided to work with what made sense and accept the feelings of uncertainty and confusion I had at the beginning. I then tried to list all the combinations of ages which might be involved in the problem. Eight combinations seemed to exhaust the possibilities; I rechecked my list several times and verified this. When I totalled these combinations I discovered that two had identical sums, and this explained the mathematician's need for an additional clue. And then I saw how the philosopher's fourth and last clue dispelled any doubt between these two combinations.

My reasoning went through several stages:

- Clarifying the information contained in the problem statement.
- Being willing to continue working in spite of a feeling of uncertainty.
- Patiently trying to list all possible cases, and rechecking these to make sure all were covered.
- Understanding *why* the mathematician was unable to solve the problem without the final clue.
- Discovering the solution to the problem in the light of the fourth clue from the philosopher.

In solving the problem, the most important stages, at which I was tempted to give up, were the second and third: when I was confronted by uncertainty and lack of clarity, and when I had to list, rather tediously and patiently, all the combinations of ages that were possible. I should try to remember, then, my need for a willingness to cope with uncertainty, and the need for slow and painstaking thought.