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ABSTRACT

The basic tenet of Programed Instruction (PI), that learning occurs best when knowledge is imparted in small increments, appears to apply to associative rather than deductive process. One may best learn definitions via association, and best learn inference via unified understandings. This hypothesis was tested by structuring two modes of presentation for a topic in economics, a PI package and a test. Two subject groups each received one of the presentations. No differences were noted between group performances. While the hypothesis that subjects learning by the text approach would do better on inferential questions and subjects learning by PI would do better on definitions was not confirmed, sex differences were noted. Males performed better using the text while females did better using PI. All subjects performed poorly on inferential questions indicating that people must be specifically and explicitly taught deductive reasoning. (The latter was not done in the text used in this study). (Author/CJ)

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DEFINITIONAL VERSUS CONCEPTUAL LEARNING

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U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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Definitional versus Conceptual Learning

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Contents

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Summary

The fundamental tenet of Programmed Instruction (PI) is that learning best occurs when knowledge is imparted in small increments. Unfortunately, it would appear that this conclusion is based on an incorrect inference from the experimental data. Because the tasks used in laboratory tests have primarily been ones which simply require the learner to make an association between two events and not tasks which require one to learn and draw deductive inferences from some principle, it is not clear that the small increment is actually the most appropriate for all situations, especially the latter. Rather one may best learn definitions via an associative process and best learn inferences via the process of acquiring a unified understanding.

This hypothesis was tested by taking subject matter from the topic area of economics and structuring two modes of presentation for it: the usual PI pattern of presenting the material in small increments, and the pattern of presenting materials in a unified package (text). Subjects were split into two different subpopulations and each read a different one of the preceding groupings. A careful analysis was made of the material to be learned and the differences between definitions and inferences were explicitly developed.

Results: It was found that subjects performed equally well regardless of mode of learning. While the hypothesis that subjects learning by the text approach would do better on inferential questions and subjects learning by the PI approach would do better on definitions was not confirmed, a significant interaction between sex and mode of presentation was discovered. Men who read the text version performed better and women who read the PI version performed better. It was also demonstrated that all subjects performed poorly on the questions in which they were required to draw inferences for themselves. This finding indicates that people cannot be expected to learn inferences unless they are explicitly taught or methods for drawing inferences are taught (the latter was not done in the text used here, in fact it seldom is in any learning setting).

Introduction

Programmed Instruction (PI) materials are being widely developed and adopted for educational and training uses. In view of the sometimes unfavorable results of PI research (Reed and Hayman, 1962; Smith, 1962; for example), the very limited degree to which some PI issues have been explored (Leib, et al., 1967) and the reservations of some researchers (Pressley, 1964; Silverman, 1960) it would appear that this enormous investment of energy and funds is somewhat premature. Granted, PI is an innovation in learning that its proponents promise will greatly increase the efficiency of education (Buckley, 1967, as a recent example). Nonetheless, the necessary theorectical underpinnings are far from being fully understood and accepted.

The fundamental tenent of PI is that learning best occurs when knowledge is imparted in small, logically sequenced increments. Unfortunately, it would appear that this conclusion, while seemingly supported by the experimental evidence, is based on partially incorrect inference from the data. Because the tasks used in laboratory tests have primarily been ones which simply require the learner to memorize or to make an association between two events (Skinner, 1961), and not tasks which require one to first learn some principle and then draw deductive inferences from it (Geisinger, 1968), it is not clear that the small increment is actually the most appropriate for all situations, especially the latter. For example, tasks in these experiments typically have been of the order: "Teach one the definition of ethnocentrism." Much less experimentation has been done on tasks such as: "Teach one how to do maintenance on heater thermostats by explaining the principle that different metals expand and contract in different amounts when subject to the same heat." It is reasonable to infer that the small incremental step approach (with learner response and feedback) is effective for memorizing definitions and like notions; certainly many participants in PI have shown an improvement in understanding (for example, see the Holland-Skinner program in elementary psychology, 1961). On the other hand, to break a complex set of statements down into small incremental steps destroys its unity. The learner is diverted from seeing the set as a whole and his attention is instead focused on the pieces of it. He has a much more difficult time drawing inferences from it.

The difference between definitions and concepts, i.e., inferences, can be nicely illustrated by examples drawn from programmed texts. The following frame (Holland and Skinner, 1961, p. 336) clearly imparts a definition to the student:

> "Sneezing which clears the upper respiratory passages is _______ behavior. However, the "imitative" sneezing by the little boy who "only does it to annoy" is _______ behavior."
> (reflex, operant)

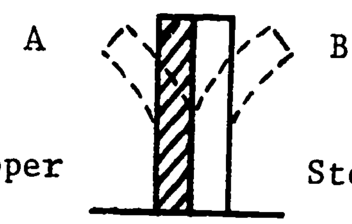
These are statements of the meaning of the words, reflex and operant. On the other hand the next set of frames explains an idea and then requires the student to draw an inference from it (Rummeler, 1965, p. 2).

1. through 6. The learner goes through statements which tell him that copper expands faster than steel when subject to the same heat. 7. Because the copper is fused solidly to the steel, it cannot become longer than the steel without bending around it. The strip below has been heated. Which part is the steel?

Bi-metal Strip

(A is the correct choice)

8. If the temperature changed from 60° to 80° would the bi-metal strip move toward A or B?



Bi-metal Strip

(B is the correct choice)

Here the student is first taught what happens when two different metals are fused and heated. He then must answer a question that requires him to apply the ideas to a new situation. Note that if this programmed text had not broken fram 7 and the material preceding it into parts, but instead had left it as one large increment it would correspond to what is called the unified or text approach in the following paragraphs.

To understand the nature of the learning process one must understand the structure of the material to be learned. Typically, such material will be a discipline or set of principles, such as anything from physics, to economics, to human relations, to basketweaving. Thus there are two important questions of concern to the psychologist. One is, what are the psychological processes of learning? The other, inseparable from the first, is what is it that is to be learned? In other words, the learning process is dependent upon the content of the material to be learned.

Let us consider the latter question first. The structure of all disciplines are similar and therefore one can discuss content in general terms. Disciplines begin with the naming of "things" where things stand for objects (including abstractions) and operations: i.e., money, books, divide by, atom, love, temperature. These "things" are normally called variables and will be so referred to hereafter. It is worth recognizing that this naming activity is not unequivocally predetermined by the setting for the discipline. The variable we call snow has eight different names for the Eskimos. The next step in any discipline is to define the variables that have been named, i.e., economics is the study of markets. The atom is the basic particle of matter (not the most elementary particle by the way). Again it is worth noting that definitions are typically couched in terms of other variables that presumably are already understood. Often a variable is defined in terms of its attributes. For example, an automobile is a machine with an engine and wheels, a place for passengers, and is capable of moving over various surfaces. The attributes listed here include both objects (i.e., wheels) and operations (i.e., moving capability). A variable may be either an object or an operation. In other words, money is a variable and is the name for an object, and divide by is a variable and is the name for an operation that can be performed on other variables.

The features constituting a discipline can now be described. First one names the variables (objects and operations). Secondly, the variables are defined and the relationships between variables are described. "A is equivalent to B", "A divided by B equals C", etc. This is the process by which all of the parts of the discipline are knitted together. From this one has the information that enables him to draw inferences on the relationship between any two or more variables. For example, the information may be provided that $A + B = C$ and that $C = D$. Here one can draw the inference as to what is the value of D, given A and B.

The difference between a definition and an inference is in the use made of the idea. A definition is the establishment of a relationship by the linking of two or more objects by one or more operations. In a definition one is naming the objects and/or operations that go together. In the example, "economics is the study of markets", economics, an object, is the name for the study of markets. In the example, "rate of return is interest rate divided by investment", divided by, an operation, is the name for the manner in which interest rate and investment are related. Thus both examples are definitions because in both, a relationship is merely established. Incidentally, the second example contains another definition: rate of return is the name for the set, interest rate divided by investment.

An inference is the use made of one or more definitions. In an inference one determines or is told what a relationship implies. Taking the second example above, one may draw two inferences: (1) holding interest rate constant, as investment increases rate of return declines and vice versa, and (2) holding investment constant, as interest rate increases rate of return increases and vice versa. Consider another example. The following two statements are each definitions. "GNP is a measure of the value obtained by a society", "GNP is consumer plus business plus government expenditure". One can draw the inference from these two definitions that consumer plus business plus government expenditure is a measure of value.

If one learns definitions alone, he may or may not see the underlying inferences. He may or may not be able to draw the correct inferences (solve the problem) when a question requiring an inference is put to him. One can say with more certainty that he has learned the inference only when either the inference itself has been taught, i.e., in the example he is taught that investment and rate of return vary inversely with each other, or when a method for deriving or finding the inference has been taught.

The notion of deriving and finding of inferences, often called heuristic search or cognitive processes has been described by such people as Newell, Shaw and Simon (1957). But the teaching of this part of any discipline has been largely ignored to date in PI texts. This is probably in part due to the view of some text writers and theorists in the field that the acquisition of inferences is a stimulus-response process. Yet the person who has been taught to recite the steps to a proof of a theorem or explain a concept may very well be incapable of formulating the correct steps to proof of a new theorem or deriving a new inference. Instead of stating an idea and then attempting to drill it in by PI techniques, text writers could present their material in such a way as to either give the participants the inference (that is tell them) or give them the opportunity to discover the relationships by providing them with appropriate methods for doing so. Since these heuristics are by their very nature merely rules of thumb, that is, they are good things to do, but they don't always work, it is necessary to orient participants towards search. They must be taught to try a tactic, get feedback on the implication, and then change direction if it does not being one closer to his goal. One way to do this is to let them follow out the consequences of any heuristic they might generate. In other words PI texts could be flexible enough to allow the participants to experiment with the ideas they generate from the material presented.

Given this as the structure of disciplines, one may now ask, what is the process by which such ideas are learned? First there is the step of having the definition or relationship being stated to the learner. The learner must learn (remember) this relationship. An aid to learning this is having it reinforced. One may do this by having the learner, after the relationship has been stated, immediately repeat back the relationship from memory and then receive reinforcement if he is correct. This is the S-R notion of establishing an association between two things by having the co-occurrence, that is the relationship between them, reinforced or pointed out to the person. This is done in a variety of ways. The person has the appropriate word or experience repeated until he associates it with the stimulus. This is sometimes thought of as reward feedback. When a person experiences a reward for associating two things he concludes that they are associated. Yet, when there are many relationships to an idea, that is, when there are many parts to be linked before closure is reached, it is possible that interrupting between each step will interfere with the achievement of closure. For example one may learn A + B = C and then C = D, but if there is a reinforcement step between the two he may later not be able to link A + B and D. Because C is not now contiguous in the two relationships he does not know (remember or understand) that the two C's are the same. We are all familiar with the experience of not understanding another because we fail to "appreciate" the context he is using. He has one context (name) in mind for a word and we have another, and unless we can link the two, we see no connection between what he is saying and what we are thinking.

This interpretation of the PI literature is suggestive of a new hypothesis:

> One best learns definitions via the associative process and one best learns inferences via the process of acquiring a unified understanding.

If true, this hypothesis has two very important implications. (1) It is indicative of a need for the typical PI text to be revised away from the small incremental step approach. That is, we should continue to use this technique for teaching definitions, but we should modify the mode of presentation into a more unified pattern of presentation when teaching inferences. (2) It is a step toward reconciliation between two divergent lines of learning theory -- associative and cognitive processes. The former emphasizes the stimulus-response aspect of learning, and this may indeed be true of definitional material. The latter emphasizes the understanding of the overall set of relationships aspect of learning, and this may indeed be true of inferential material. In one of the few studies comparing material presented in increments and packages, Williams (1963) found that those given the material in increments performed better than those given the material in a package (at the $p < .02$ level). Since Williams used the Holland-Skinner program (which was largely definitions), one would expect this outcome.

Method

It is possible to test this hypothesis with a fairly rigorous but straightforward experiment. One takes some topic area, say economics, that has definitional and inferential categories. He then structures two modes of presentation for the subject matter. In one mode he sets up the usual PI pattern of presenting the material in small increments with active participation and immediate feedback. In the other mode he presents the material in a unified complete package in text form. This results in the following two groups of subject matter:

1) definitional and inferential material in text form (text)
2) definitional and inferential material in increments (PI)

He splits his subjects into two different subpopulations and has each read a different one of the preceding groupings of subject matter. He tests subjects on pre and post test criterion examinations containing both definitional and inferential questions. In accordance with the hypothesis, the PI group should improve significantly more from pre to post test than the text group on the definitional portion of the examination and the text group should improve significantly more than the PI group on the inferential portion of the examination.1/

1/ The initial plan was to divide the material to be read into two

Text, subjects, and examination

The text to be read was chosen in accordance with the criteria that: (1) it have about half definitional and half conceptual material, (2) it was written in good programmed learning technique form. The PI text, Attiyeh, Lumsden, and Bach, Macro-economics (1964) met this criterion. The first three chapters, including graphs were taken from the book and prepared in two versions on 5 x 8 cards. One version was just like the PI text form with the usual blanks, the text version was like the first except that the blanks had been filled in with the result that the material looked like a regular paragraph of text. In the PI version subjects were provided with sheets on which to write their answers and with 3 x 5 cards on which the correct answers were written.2/ They were carefully monitored to insure that they always filled in the blanks. In both conditions subjects had scratch paper on which to take notes if they wished to do so.

Several considerations were taken into account to insure that the data would be representative. The subject pool was randomly drawn and was composed of students who have not had and are not taking economics. This made the material being presented the sole input during the experiment and prevented any confounding of inputs to subjects. One might argue, "Why not use students from your classes? You don't have to pay them and they learn something besides." The apparent savings from doing this is, in the end, really a cost. One loses a very important control over the experiment, for he would no longer know exactly what all the subjects are taking in as inputs. They might very well be learning something from the regular text and lectures for the course -- and unfortunately not all

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parts, half dealing with inferences and half with definitions. Then each half was to be presented each of the two ways, text and PI. Thus there would have been four groups of subjects, one-fourth would have read inferential material in text form, one-fourth in PI form, one-fourth definitional in text form, and one-fourth in PI form. This design was changed to the design described in the text after pilot testing and extensive review of the material and the underlying nature of disciplines. It was found that the material could not logically be broken apart. The pieces needed for each were also needed for the other and neither could stand alone. Going from four conditions to two also resulted in its being possible to reduce the sample size without changing the expected level of significance.

2/ The initial plan was to have subjects receive and respond to the material over teletypes, and to then automatically record their responses and the time it took them to reply. During the course of the year a study was reported in the literature (Poulton, 1969) in which it was demonstrated that reading material in all capital letters has an inhibiting effect on performance. Since this is how the information would have been presented over the teletypes it was decided to switch to a typewriter card form.

of them would learn the same amount. Furthermore, as Swinth (1968) has observed, when a PI text is used in conjunction with a regular text and lectures the students get no marginal benefit from it. Thus they would have little incentive to really learn from the experimental material. At the same time, it is important to have each subject participate for several hours to get him beyond initial learning about the PI technique and beyond the novelty stage. Also, it takes several hours to transmit enough material for a subject to really know anything about the topic area.

Therefore, to make the results of the study representative, the sample was randomly drawn from the University of Kansas Freshman class, with the students composite score from their American College Testing Program Admissions Examination (ACT) serving as the profile. The norm data on this aptitude test and the final sample used in the experiment are shown in Table 1. The distribution for the sample used in the experiment is

Table 1

Norm Data ACT Scores

ACT Composite Score	Percentile Scores			
	University of Kansas	Study Sample	Institutions Offering Ph.D.	College Bound Seniors
28-36	83	77	92	95
26-27	66	52	80	89
23-25	38	23	55	72
20-22	19	12	31	52
1-19	1	1	1	1

reasonably representative of the University of Kansas distribution. It has a higher average aptitude than the national average for students bound for institutions offering the doctor of philosophy (the University of Kansas group) and a much higher average than that for all college bound high school seniors taking the ACT examination.

Subjects were randomly drawn from the freshman class over the University as a whole. A list of 300 names, randomly selected was provided by the Registrars Office. This list contained each student's admission aptitude test score (ACT) and his sex. This pool was divided into five segments of equal size by aptitude score. From each segment an equal number of persons were contacted and asked to participate in the experiment. They were advised that they would be paid. Of the 124 individuals contacted 37 refused to participate, 27 could not participate because they had jobs, classes, or other regular commitments that prevented them from being able to appear at any of the scheduled times, 8 had already had economics or were now taking it, and 52 became the final pool used in the experiment. Once this pool was established, subjects were matched by aptitude and randomly allocated to one or the other of the experimental conditions.

The pre-post test was constructed to measure the material read by the subjects. The text had 100 fill in and multiple choice questions. These 100 questions were selected to cover the full set of reading materials and the distribution of questions reflected the distribution of ideas in the material. Sixty-six of the questions were definitional and 34 were inferential. The latter 34 included questions over inferences that had been taught in the text and over inferences that were left up to the reader to draw. The test was extensively pretested with both graduate students in economics and naive lower classmen to insure that it was conceptually correct on the one hand and that the questions were understandable on the other. Pilot subjects were also paid to try to "game" the examination, that is, see how many questions they could get right by taking advantage of the way questions were worded or by using the information in one question to answer another question. Such opportunities were then eliminated.

The experiment was administered over three weeks with any given set of subjects participating in one hour to two and a half hour sessions each day for 5 days. Each set of subjects included people from both conditions and all ranges of aptitude. A typical set ran as follows: An experimenter, who was always present, first gave the subjects the pretest. This typically took about an hour. After the pretest subjects were told that they would be paid $1.00 per hour for their time (tests and reading) and 20 cents for each additional right answer on the post test. At the beginning of the next session they were given their material to read with appropriate explanations on filling in the blanks, etc. At the end of the two and half hours they were stopped. This was repeated three more days. If a subject finished his material early he could leave or remain and review it. On the fifth day the post test was given, followed by a questionnaire and debriefing. After all the experimental sessions were over the tests were scored, subjects were paid and the results were explained to them.

Twenty-four matched pairs were run, 11 pairs of men and 13 pairs of women. An additional four subjects (2 men and 2 women) were also run for whom the person who was to be matched did not participate in the experiment for one reason or another. In the analyses to follow, those based on the matched set have a total N of 48 and all others have an N of 52.

Results

The prediction by the hypothesis is that subjects reading the text version of the material will change more on the inferential questions from the test than the subjects reading the programmed instruction version. Similarly subjects reading the PI version should change more on the definitional questions than subjects reading the text version. This expectation was not confirmed in either case. The mean difference in score for the inferential portion of the test was 1.45 points with the text subjects having the higher mean. The mean difference for the definitional portion was 1.13 points, again with the text subjects having the higher mean. Since the students had previously been matched both for aptitude and sex, the variance in the two groups could be assumed to be equal and the standard error of the differences between scores for each pair could be used for analysis. The standard error of the differences between paired scores was 1.21 in the first case and 2.28 in the second. With 24 pairs the mean difference is not significant in either case.

As an alternative method of evaluating the data and to check for other effects, analyses of variance were performed on the data using all the subjects ($N = 52$). The change for both the inferential questions and the change for the definitional questions were analyzed. In each case the subjects' change score on the inferential (definitional) questions was the dependent variable. Two factors, (1) sex and (2) the version of the material read were the independent variables, and each subject's aptitude test score and total pretest score were included as covariates. There was no significant effect on change scores due to sex or version of material read for either the inferential or the definitional questions ($F < 1$ in all four cases). Surprisingly, there was a significant interaction between sex and version read for both the inferential questions ($F = 6.90$, $p < .01$) and the definitional questions ($F = 8.05$, $p < .01$). The mean change for the men was higher under the text version and the women under the PI version in both cases.

Change score was related to the covariates in two cases. Pretest score was inversely associated with change on the inferential questions ($F = 6.06$, $p < .05$) and aptitude was positively associated with change on the definitional questions ($F = 7.29$, $p < .01$). In other analyses it was found that there was not a significant correlation between study time and change scores for either of the subsets of questions.

Since some of the questions on the test measure inferential learning and some measure definitional learning, one can ask, for any given question which version of instruction, text or PI, results in the better percent correct. In Table 2 the questions have been broken down into inferential and definitional groupings. The inferential questions have further been broken down into those that required the subjects to draw an inference and those where the inference was actually taught. The definitional questions have been broken down into those that measure the recall of the definition of operations and those that measure objects. The first row of the table reports the frequency with which text learners had a higher percent correct than the programmed instruction learners. The second row reports the reverse (programmed instruction higher percent correct than text). The third row indicates the frequency with which the percent correct was equal. The fourth row indicates the mean percent correct in each case. Note that in all cases the frequency is in favor of those reading the text version but only in the first column, where the subject must draw his own inference, is the trend really pronounced. Note too, the mean percent correct falls off considerably in this column relative to the other three.

The text was properly constructed to measure learning as can be seen by the overall scores. The mean pretest score over the 52 subjects was 21.1, the mean post test score 60.8, and the mean change score 39.2. Thus subjects did not top out on the post test; that is, they did not score so near 100 that differences were suppressed. Subject learning did

Table 2

Breakdown of Questions by Type of Idea

Frequency Comparison (%)	Inferential Questions: Inference must be drawn by subject	Inferential Questions: Inference taught to subject	Definitional Questions: Operations	Definitional Questions: Objects
Text % > PI %	6	13	9	27
PI % > Text %	1	12	6	22
Text % = PI %	2	-	1	1
Mean percent correct on post test (out of 100 questions)	34.9%	67.2%	59.2%	61.8%
Number of questions from test	9	25	16	50

occur and was amply measured as reflected by the sizable mean change score. Subjects in the two conditions were not different: The mean aptitude score in the text condition was 24.7 and in the PI condition 24.65; the mean pretest scores were 20.95 and 21.35 respectively; and there were the same proportion of men and women in the two conditions. As was pointed out earlier, subjects in the two conditions were matched on aptitude and sex for some of the analyses. The mean time spent studying the material was nearly the same in both conditions, 433 minutes in the text condition, and 440 in the PI.

Conclusions

A number of controls were established over the experiment to insure that the objectives of the study would be achieved. The sample was representative of the University of Kansas population, the subjects were truly naive, there was no confounding from class and other experiences, subjects were motivated to participate, their behavior was tightly controlled, and subjects were carefully allocated to the two conditions to maintain balance. The material read by the subjects and the examination were both carefully prepared and reviewed to insure that they communicated and measured the intended information.

The usual presumption in the PI literature, that the PI approach is better than the usual text approach, was not substantiated by the data. The results of this study are that subjects learn equally well under both modes of presentation. There was no significant difference between the text and PI conditions for either the inferential or the definitional questions.

At the same time, the major hypothesis of this study was not confirmed either. Subjects reading the text version did not perform better on the inferential questions and subjects reading the PI material did not perform better on the definitional questions. The really important finding as far as mode of presentation is concerned, is the interaction with sex. This interaction indicates a fundamental difference in the way in which the sexes learn, or at least have been taught to learn. The men performed better under the text approach and the women under the PI approach for both inferences and definitions. Why should this be; what is it about the learning processes of the sexes that could produce this? In other words this result raises a number of questions that have not previously come up in the PI literature. It may very well be the basis for explaining the controversy over text versus PI raised by past studies. The reason why in some cases the PI approach has been found to be better, in others there has been no difference and even in others the reverse trend has been true, may very well be that, as found here, here, the sexes were differentially contributing to the observed results.

As far as inferential versus definitional learning is concerned, the mode of presentation appears to make no difference, at least for taught material. Both inferences and definitions that have been taught are about equally well learned under both text and PI formats. Likewise, both formats result in adequate learning of such taught material. On the other hand, inferences left to the learner to draw for himself are not learned adequately. In light of the data it appears that the learner should be taught the methods and heuristics for drawing inferences. Since this was not done in the reading materials used in this study, it is not possible to test this idea with the data at hand.

In learning inferences then what matters is whether or not the learner has been guided to all the possible inferences: (1) either he should have them explicitly taught and/or (2) he should be shown how to draw inferences. The latter is almost never done in most courses. The classic example is in the typical mathematics course where the instructor presents the theorems and the proofs, i.e., the definitions, but does not show how one establishes a theorem. He does not go through the process by which he inferred the answer. Note that a discipline can be fully described by its definitions but one cannot necessarily solve problems with this information. The latter ability is not automatically obtained by being taught the definitions. The person must be taught the inferences or how to draw them.

We often regard it as boring to have the inferences told to us. Mathematics would lose its appeal if all theorems were done for us, if all algebra problems were solved for us. In fact the most important purpose of many disciplines is to solve new problems. Thus in economics, social sciences, engineering, etc., we want people to be able to solve problems that we haven't yet faced. In light of this study one may conclude that to achieve this skill individuals must be taught how to draw inferences.

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