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ABSTRACT

Following some years of eclipse by the basics, imparting thinking ability to students is once again emerging as the primary goal of public education. How to teach thinking skills, is, however, subject to question. For example, not only is the domain of the higher order skills broad and imprecisely specified, there is also considerable naivete in the public's perception of the conditions under which thinking skills are learned. In particular, recent legislative actions are based on unexamined assumptions about the conditions under which these skills are learned. In response to the reform rhetoric, many states have mandated increased science and mathematics requirements for all students for high school graduation. These requirements are based on the belief that reasoning, problem solving, and learning skills are best taught in these courses. However, there are concepts that educators should be aware of; for example, (1) not all students have the ability to attain higher order cognitive skills; (2) mathematics and science are not the only ways for teaching these skills; (3) high school is too late to begin teaching thinking skills; (4) experiences with physical systems play a considerable part in development of basic mental operations; (5) less able students need detailed instruction; and (6) rote performance is inferior to performance with understanding. It is important that educators keep these ideas in mind as they look for ways to teach thinking skills. Vocational education can play an important role in teaching these skills; science and mathematics are not the only way. (Several problem-solving examples are provided in this paper.) (KC)

Teaching for Workplace Success

Audrey Champagne

Occasional Paper No. 113

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Occasional Paper No 113

TEACHING FOR WORKPLACE SUCCESS

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1986

FOREWORD

A frequent call emanating from the many recent education reform reports is the increased emphasis on the basics and on higher academic standards To a great extent, this is the logical result of our gradual discovery that we have an appalling percentage of people in this country who are seriously lacking in communicative and qualitative skills Estimates of functional illiteracy among adults are as high as one in three That is, about 60 million adults cannot read at an acceptable level

The initial reaction of vocational education to increased graduation requirements has been that this will hurt vocational education by leaving students less time for vocational classes Most vocational educators feel strongly that requiring more academic courses will not necessarily be helpful to large numbers of students and that multiple strategies are needed The National Commission on Secondary Vocational Education, in its report *The Unfinished Agenda*, found that "students perceive vocational courses as time for doing, not thinking, as easy, not difficult, as practical, not abstract In the same way, students perceive courses in physics and mathematics as time for thinking, not doing, as difficult, not easy, and as abstract, not practical Both perceptions are severely limiting to students, but perpetuated by the traditions and practices of the schools" (*The Unfinished Agenda*, 1984, p 12) They need to be changed

Audrey Champagne brings a very relevant background to the consideration of how best to prepare students for the workplace She has a bachelor's and a master's degree from the State University of New York at Albany in Chemistry, a Masters of Education from Harvard in Science Education, and has taught science at the elementary and secondary levels in Nigeria as well as in this country After receiving a doctorate in education from the University of Pittsburgh, she joined the renowned Learning Research and Development Center (LRDC) at that university From 1970 to 1984 Dr Champagne served as codirector of various science education projects She has spent the last 2 years as project manager for the School Science and Technology project at the American Association for the Advancement of Science in Washington, D C Dr Champagne has an extensive list of publications, has served as a consultant and on numerous committees in this country and abroad, and has been the recipient of various honors and awards

On behalf of The Ohio State University and the National Center for Research in Vocational Education, I am pleased to present this seminar paper by Dr Audrey Champagne

Robert E Taylor
Executive Director
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TEACHING FOR WORKPLACE SUCCESS

Introduction

Thinking its importance in the workplace and its enhancement through formal instruction are the two topics addressed in this paper. Following some years of eclipse by the basics, imparting thinking ability to students is once again emerging as the primary goal of public education The demand for improved thinking skills is in part a response to a weakened economy, and as such has distinct political overtones These conditions aside, however, the fact remains the nation expects its schools to effect significant improvement in the thinking skills of all its youth—even the average ones

Nowhere is the demand for sound thinking greater than in the workplace The implications for vocational educators are clear The means to achieve the ends are not This paper discusses some of what is known about the conditions under which thinking skills are enhanced and recommends some courses of action for the vocational education community

Education and the Economy

The rhetoric of educational reform predicates the nation's economic productivity on a work force composed of individuals who are problem solvers capable of learning the new skills required by evolving technologies However, employers report that many high school graduates do not have the requisite skills to perform adequately in the workplace They complain that their remedial training costs are excessive and are increasing (Eurich 1985). A 1985 survey of companies indicated that reasoning deficiencies are a weakness of workers in most of the job categories for which data were collected (Center for Public Resources 1982) *High School and the Changing Workplace*, a report of the Panel on Secondary School Education for the Changing Workplace, National Academy of Science, projected the characteristics of tomorrow's workplace and specified the type of worker who will prosper in it The panel concluded that

> the major asset required by employers of high school graduates seeking upwardly mobile careers is the ability to learn and to adapt to changes in the workplace The continual evolution of work functions will require that workers master new knowledge and new skills throughout their working lives The ability to learn will be the essential hallmark of the successful employee (Panel on Secondary School Education 1984, p xi)

This conclusion is based on the projection that average workers will hold 10 different jobs during their work lives and that tomorrow's workplace will be characterized by change These ideas are not unique to this report They are, in fact, remarkably similar to the conclusions in two reports that predate it *Action for Excellence* (Task Force on Education for Economic Growth 1983), and *Living Tomorrow An Inquiry into the Preparation of Young People for Working Life in Europe* (Deforge 1981) Quotes from experts cited in each of these three sources illustrate the similarities

High School and the Changing Workplace

A person who knows how to learn is one well-grounded in fundamental knowledge and who has mastered concepts and skills that create an intellectual framework to which new knowledge can be added (p 17)

Competencies include the ability to reason (p 19)

The capacity to reason and solve problems is the central indication of an educated person Throughout their working lives, individuals will encounter problems or situations with various possible solutions. The ability to understand the consequences of alternative courses of actions is an essential condition for success in employment Well-developed reasoning capacity requires a person to be able to do the following

- Identify problems
- Consider and evaluate possibilities
- Formulate and reach decisions logically
- Separate fact from opinion
- Adjust to unanticipated situations by applying established rules and facts
- Work out new ways of handling recurring problems
- Determine what is needed to accomplish work assignments (pp 20-21)

Action for Excellence

Higher order skills [are] inference, analysis interpretation and problem-solving skills (p 24)

Reasoning competencies are these

- The ability to identify and formulate problems, as well as the ability to propose and evaluate ways to solve them
- The ability to recognize and use inductive and deductive reasoning and to recognize fallacies in reasoning
- The ability to draw reasonable conclusions from information found in various sources, whether written, spoken, tabular, or graphic, and to defend one's conclusion rationally
- The ability to comprehend, develop, and use concepts and generalizations
- The ability to distinguish between fact and opinion (p 50)

> Polyvalence suggests the idea of similar mental operations shared by several techniques or, even better, a body of knowledge and skills capable of being used to handle both work and life situations (p 54)
>
> forms of knowledge and behavior taken at a particular level of generalisation [sic] show that the same skills are mobilised [sic] in both occupational and life situations (ibid)
>
> general operational skills used in determining why certain processes or actions precede or follow others in work situation (p 55)
>
> This involves four steps identifying the problems, considering how to deal with them, taking action, and checking (ibid)

These three sources are remarkably similar in their specifications of the mental skills that the successful worker needs One difference is that only the National Academy of Science (NAS) panel report mentions learning-to-learn skills. A noteworthy feature of the descriptions from these three sources is their imprecision Such imprecision is characteristic of most descriptions of the thinking skills The absence of any such detailed specifications makes systematic attempts to teach or test for them difficult if not impossible. Developing exact, detailed specifications for these skills is a priority on the agenda of cognitive psychology. This is a scientific task of major proportions The range of mental skills is broad and the challenge to develop specifications for them is considerable, as the following discussion will illustrate.

Figure 1 1 depicts a cognitive skill typology. Its function is to illustrate the breadth of the higher order cognitive skills domain. The typology is in the form of a tree structure that successively divides the domain of cognitive skills into categories. There are three major divisions depicted in the figure The first division separates the domain into two categories—those that are lower order and those that are higher order. An example will help to make this distinction clearer

The algorithm for teaching subtraction with borrowing is, according to this typology, a lower order cognitive skill. Algorithmic skills have the following characteristic in common: they can be taught as a collection of procedures that, if accurately executed, will produce a correct answer to a problem or successful completion of a task. In contrast, the ability to solve arithmetic word problems is an example of a higher order cognitive skill. This ability is so classified because there is no set of procedures that can be specified to produce a correct solution to all arithmetic word problems, even though a limited number of problem types exist Word decoding and text comprehension are verbal analogues to subtraction with regrouping in word problems.

The second major division in the figure produces two categories of higher order cognitive skills—generic and task specific. Generic cognitive skills are applicable across situations and subject-matter domains. The third major division—task-specific skills—produces three task-specific categories: problem solving, test comprehension, and learning to learn. These skills are applicable only to certain kinds of tasks. Figure 1 2 specifies some of the component or sub-skills of problem solving and learning.

There are other task-specific categories beside learning, problem solving, and comprehension that are not included in the typology. Furthermore, the typology does not, include all categories of thinking skills Given that the typology is far from complete, it still conveys the breadth and complexity of thinking skills that schools are expected to teach

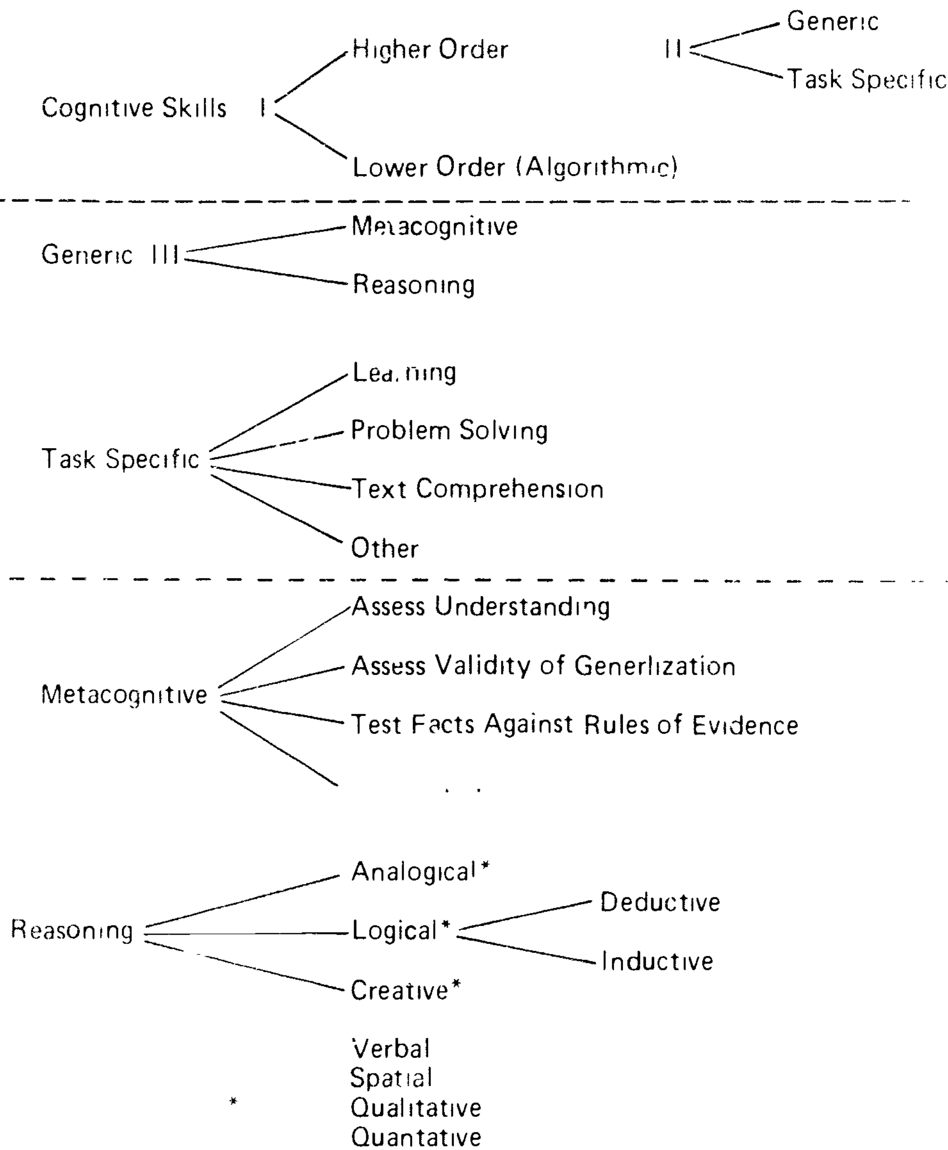

Figure 1.1. A typology for cognitive skills

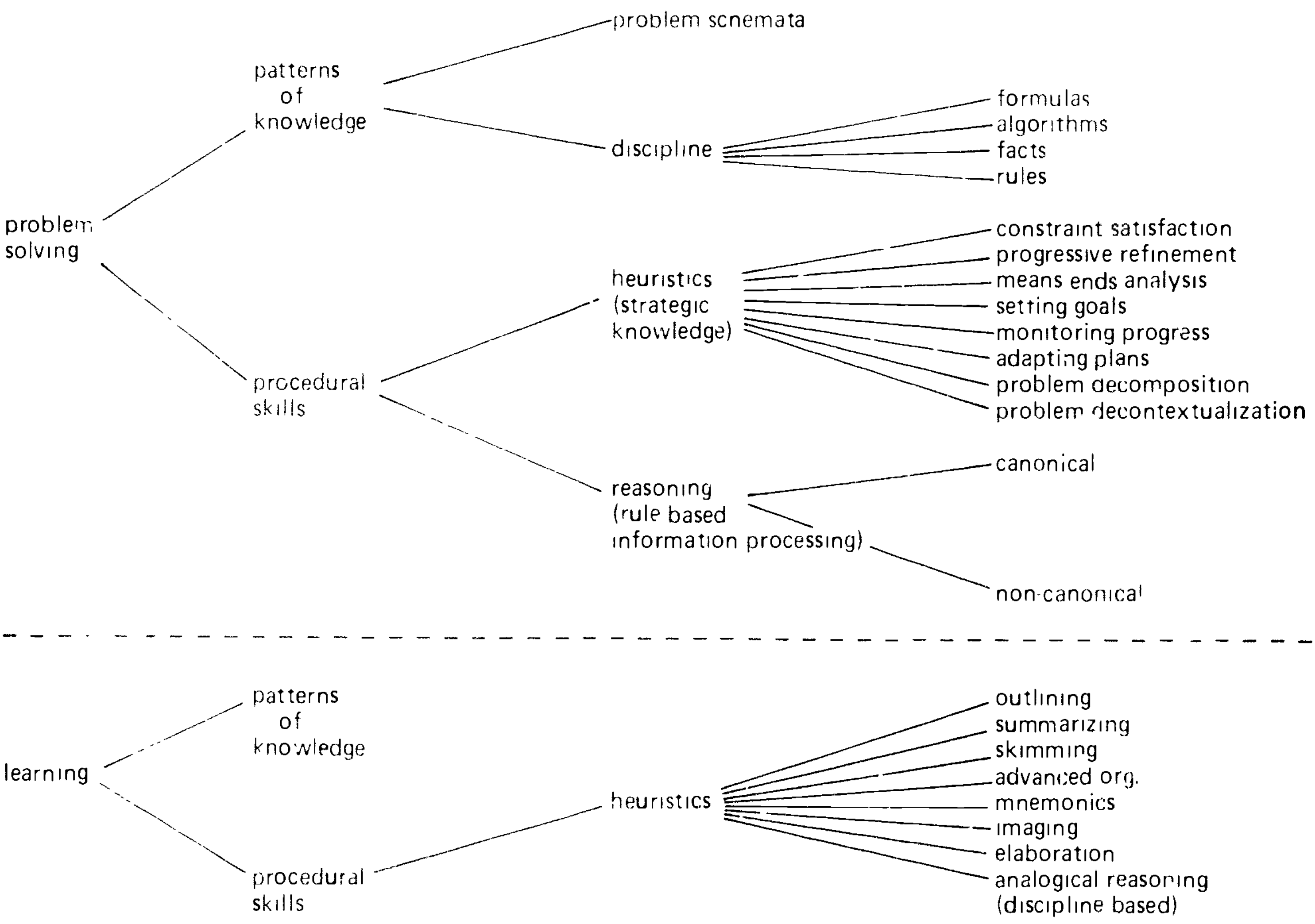

Figure 1.2. A typology for cognitive skills

For example, not only is the domain of the higher order skills broad and imprecisely specified, there is also considerable naivete in the public's perception of the conditions under which thinking skills are learned In particular, recent legislative actions are based on unexamined assumptions about the conditions under which these skills are learned In response to the reform rhetoric and conclusions such as those of the NAS panel, many states have mandated increased science and mathematics requirements for all students for high school graduation Educational reformers and state legislators alike base their recommendations on the implicit belief that reasoning, problem solving, and learning skills—the so-called higher order cognitive skills--can be taught by and are best learned by studying science and mathematics This belief has considerable intuitive appeal Scientists and mathematicians are, after all, skilled at problem analysis, even when the problems are outside their field of expertise Scientific modes of thinking and mathematical symbolism seem to transfer to practical situations and to social and economic problems. As appealing as the belief is, however, no convincing empirical evidence demonstrates its validity. The challenge facing education is to engender higher order cognitive skills in all students and to do so in the face of several crucial, unanswered questions (1) What exactly are the higher order cognitive skills? (2) Can they be taught? and (3) Are science and mathematics courses the best places to learn them? In the absence of definitive answers to these questions, actions to be taken by educators must be based on partial information and must rely heavily on experience Certain of the propositions that follow are based on emerging research from cognitive and developmental psychology, others, on experience The list contains some caveats and potentially fruitful courses of action for educators faced with the challenge of teaching thinking

The Teaching and Learning of Thinking Skills

The following eight propositions relate to the teaching and learning of thinking skills

- Serious consideration must be given to the possibility that attaining the higher order cognitive skills is not equally possible for all students Alternatively, for some individuals, the time and resources needed to achieve the goal are too great Whatever the position taken on this question, there is agreement that schools can do a significantly better job in improving students' thinking skills

- Learning mathematics and science is not the only way for students to attain thinking skills In fact, these subjects have certain characteristics that make them undesirable vehicles for learning thinking skills Many students of average ability, young women, and students from certain ethnic groups do poorly in science and mathematics courses as they are currently taught Faced with recurring failure, these students do not elect to take these courses unless they are required to do so Perhaps students in these categories would learn the skills better if they were presented in the context of more practical, real-life situations such as those studied in vocational education programs

- High school is too late to begin teaching thinking skills The cognitive prerequisites for these skills are built in the elementary grades Failure of high school students to become facile thinkers can be attributed in part to the absence of a grounding in the prerequisites

- Building on the third proposition, the mental skills and concepts that children learn in the elementary school are the foundation on which their higher order cognitive skills are built If these concepts and mental skills are not learned, the higher order skills do not develop

- Much of what is taught in elementary school is considerably more complex than most people recogni:

- Experiences with physical systems play an important role in the development of basic mental operations Thinking reversibly, an example of a mental operation, is characteristic of adult thinking and of most children's thinking beyond 8 years of age To test if a child can think reversibly, the child is shown two spheres of the same diameter made from clay Once the child agrees that both balls have the same amount of clay in them, one of the spheres is molded into a cylinder. Then the child is asked if both objects contain the same amount of clay Before the age of eight, most children believe that the cylinder has more clay in it The child does not reason that if the cylinder is remolded into a sphere, it will have the same diameter as before That is, the child does not have available the mental operation of reversibility The theory is that the mental operations are learned by experiences with transformations of physical substanc

- Students who are academically less able benefit from instruction that is highly detailed Detailed instruction builds the rich knowledge structures that back up performance with understanding When instruction presents information in small bits, students have the sense that they are learning and are motivated to continue learning

- Rote performance is inferior to performance with understanding A student who performs with understanding can both perform a procedure and explain why the procedure produces the desired results The cost-benefit ratio of instruction that produces understanding is high If students understand, they remember better, they can reconstruct information when it is forgotten, they can use the information or procedure to solve problems, and they have the skills and conceptual framework for further learning

A Problem

At this point, it will be useful for you to think about this problem You know that 2,000 minus 567 equals 1,433 Under what conditions does 2,000 minus 567 equal 1211? As you think about this problem, try to keep track of the information and strategies you use to solve it If you are having difficulty thinking of an approach to the problem, see if you can remember how to represent the number 567 in base eight

About Understanding

This subtraction problem is not an acad mic one It is in fact a minor variation on the assignment given to me on the first day of my first job out of high school The second example is correct for base eight, or the octyl system of numeration The problem has practical importance because computer systems function with numeration systems other than base ten—often they use base two or base eight

The worker with a good understanding of base ten numeration is more likely to solve the subtraction problem and will probably learn how to do numerical calculations in other systems more quickly Unfortunately, most children do not have the opportunity to learn arithmetic procedures and the mathematics understanding on which these other systems are based Most elementary arithmetic is taught as rote procedures Few elementary teachers can explain why the procedures specified in the commonly taught arithmetic algorithms must be done as they are They cannot explain, for example, why, when doing a multiplication problem, the columns that are added after multiplying are not lined up, but that each succeeding row is moved one column to the left

Why should we be concerned with this lack of understanding? It usually does not affect routine performance Most members of the adult population can do numerical calculations with reasonable accuracy however, they cannot apply the procedures to unfamiliar situations Algorithms alone are insufficient to solve novel problems Applying the subtraction algorithm to base eight requires some modification in the procedures of the algorithm These necessary modifications can be made only if the information stored in number symbols is understood

Specification of What is to Be Learned

How can understanding be achieved? Understanding subtraction implies both knowing the algorithm for subtraction with borrowing and knowing the information that is stored in the number symbols used. The algorithm, a set of procedures, is presented in figure 2 The information contained in the number system is presented in figure 4

The modes of representation for the algorithm and the information in the number symbol are similar to those used by cognitive scientists when they represent the procedural and propositional knowledge stored in computers Figure 3 is called a production system, figure 4, a semantic network

Production systems are formal representations of humans' knowledge of procedures Subtraction with regrouping is an example of a procedure, an arithmetic procedure Since subtraction can be performed in many different ways, production systems modeling the procedure can have many different forms SUBTRACT SYNTACTIC, shown in figure 4, is a production system for doing subtraction as it is usually taught in American schools If the production system were written in a programming language and inputed into a computer, the computer would perform subtraction problems in a way that mimics a person performing the algorithm.

Production systems are composed of parts called productions. A production is similar to a rule it specifies conditions, and it indicates actions to be performed if the conditions are met. One of the conditions of a production is having a goal. The other conditions describe stages in the completion of a problem and situations that may be encountered in its solution SUBTRACT SYNTACTIC has 12 productions. Each of the productions has a condition that is a goal. Production 2 has a second condition that describes a state in the execution of the production system, namely, that no columns have been processed Production 7 has a second condition describing a situation that can occur when doing a subtraction problem: the bottom number (in a column) is less than or equal to the top number. Writing production systems is a useful activity for the instructional designer. It forces the designer to specify all the procedures that the student is expected to learn It also highlights the organization of the procedures and the conditions under which the application of a procedure is appropriate. These are all elements of what the student needs to learn to apply the procedure successfully.

The productions of SUBTRACT SYNTACTIC operate on numbers To perform the algorithm with understanding, a person needs to know the information that is coded in the number symbol The information coded in a base ten number symbol is represented in figure 3 This form of representation, called a semantic network, consists of nodes and links. At each node (ellipses) there is a concept. Each of the nodes is connected to other nodes via a link (arrow) on which is written a verbal statement of the relationship between the concepts Some of the information coded in the number symbol is as follows.

- Zero is a digit
- One is a digit

- Two is a digit
- Three is a digit
- Four is a digit
- Five is a digit
- Six is a digit
- Seven is a digit
- Eight is a digit
- Nine is a digit

Each digit has a position in the symbol, each digit has a value name The digit's value name depends on its location Each digit has a value The right-most digit's value name is "ones" The right-most digit has a value of the digit's value (3) times one

This is only a partial list of the possible propositions Clearly, a complete list of propositions would be very long Comparison of the length of the partial list with the semantic net or network illustrates the net's property of conciseness More important to this paper, it also illustrates the large quantity of information stored in number symbols.

A first step in developing understanding is to specify what a person needs to know to perform successfully Production systems are useful tools to represent knowledge about procedures—the how-to knowledge Semantic nets are useful representations of propositional knowledge—knowledge that provides meaning

After the underlying knowledge is specified, how does the teacher go about presenting it to the student? This is where procedures on physical objects become important, especially for elementary students If you are still struggling to remember how to represent a number base eight, the production system, GROUP, in figure 2 will tell you how to do it GROUP describes the procedures for writing the number that tells how many objects are in a collection. The production system is written for base ten, but it is very easy to adapt the productions to base eight You just have to remember that the counting string in base eight is one, two, three, four, five, six, seven, one-oh, one-one, one-two, and so forth. Wherever there is a ten in the production system change it to a one-oh. Take a handful of paper clips and try it.

The procedure that is incorporated into the production system is a recursive one If you are working in base ten, you make all possible groups of 10's, then you make all possible groups of 10's of 10's (hundreds); then all possible groups of 10 hundreds (thousands) Any ungrouped objects are the ones. These operations, grouping and recursive grouping, that the student performs on the objects are analogues of the mental operations

The mental operations that are learned for base ten are generic—they are applicable in different contexts. For example, the procedures for recursively grouping objects by 10 to determine the number of objects in a collection can be applied to determine how to represent the number of the objects in another base It also teaches the concept of a recursive procedure, a type of procedure that can be applied in many situations, including computer programming and industrial processes such as packaging

1

IF the goal is to write a number that represents the number property of a collection of objects without counting beyond ten

AND a digit has been written for the ones

THEN STOP

2

IF the goal is to write a number that represents the number property of a collection of objects without counting beyond ten

AND the cubes have not been grouped

THEN set a subgoal to group the unit cubes by ten

3.

IF the goal is to write a number that represents the number property of a collection of objects without counting beyond ten

AND the cubes have been grouped

AND no number has been written

THEN set a subgoal to write a digit that represents the number of groups of one hundred

4

IF the goal is to write a number that represents the number property of a collection of objects without counting beyond ten

AND the digit has been written that represents the number of groups of one hundred

THEN set a subgoal to write a digit that represents the number of groups of ten

5

IF the goal is to write a number that represents the number property of a collection of objects without counting beyond ten

AND there are no cubes grouped by hundreds

THEN set a subgoal to write the digit that represents the number of groups of ten

6

IF the goal is to write a number that represents the number property of a collection of objects without counting beyond ten

AND there are no cubes grouped by hundreds or tens

THEN set a subgoal to write the digit that represents the number of ungrouped ones

7

IF the goal is to write a number that represents the number property of a collection of objects without counting beyond ten

AND a digit has been written that represents the number of ungrouped ones

8

IF the goal is to write a digit that represents the number of groups of one hundred

AND there are cubes grouped by hundreds

THEN count the groups of one hundred and write the digit that represents the number of hundreds

POP the GOAL

Figure 2. Production system—GROUP

9

IF the goal is to write the digit that represents the number of groups of ten

AND there are cubes grouped by tens

AND there is a digit that represents the number of groups of one hundred

THEN count the groups of ten and write the digit that represents the number of groups of tens to the left of the hundreds digit

POP the GOAL

10

IF the goal is to write the digit that represents the number of groups of tens

AND there are cubes grouped by tens

AND there are no cubes grouped by one hundred

THEN count the groups of ten and write the digit that represents the number of groups of ten

POP the GOAL

11

IF the goal is to write a digit that represents the number of groups of ten

AND there aren't any cubes grouped by tens

AND there are cubes grouped by hundreds

THEN write a zero to the right of the hundreds digit

POP the GOAL

12

IF the goal is to write a digit that represents the number of ungrouped ones

AND there are cubes grouped by one

AND there is a number written for the number of groups of ten

THEN count the cubes and write the digit to the right of the tens digit

POP the GOAL

13

IF the goal is to write a digit that represents the number of ungrouped ones

AND there aren't any cubes grouped by ones

THEN write a zero

POP the GOAL

14.

IF the goal is to group the unit cubes by ten

AND there are ten ones at location 0

THEN make one ten from the ten ones and move the ten to location T and set a goal to group the tens by ten

15

IF the goal is to group the unit cubes by ten

AND there are more ungrouped ones

AND there are not ten ones at location 0

THEN put one cube in location 0

Figure 2. Production system—GROUP (continued)

16

IF the goal is to group the unit cubes by
tens

AND there are less than ten ones at
location O

AND there are no remaining ungrouped ones

THEN POP the GOAL

17

IF the goal is to group the tens by ten

AND there are ten tens at location T

THEN make one hundred from the ten tens
and move the hundred to location H

18

IF the goal is to group the tens by ten

AND there are less than ten tens at location
T

THEN POP the GOAL

Figure 2. Production system—GROUP (continued)

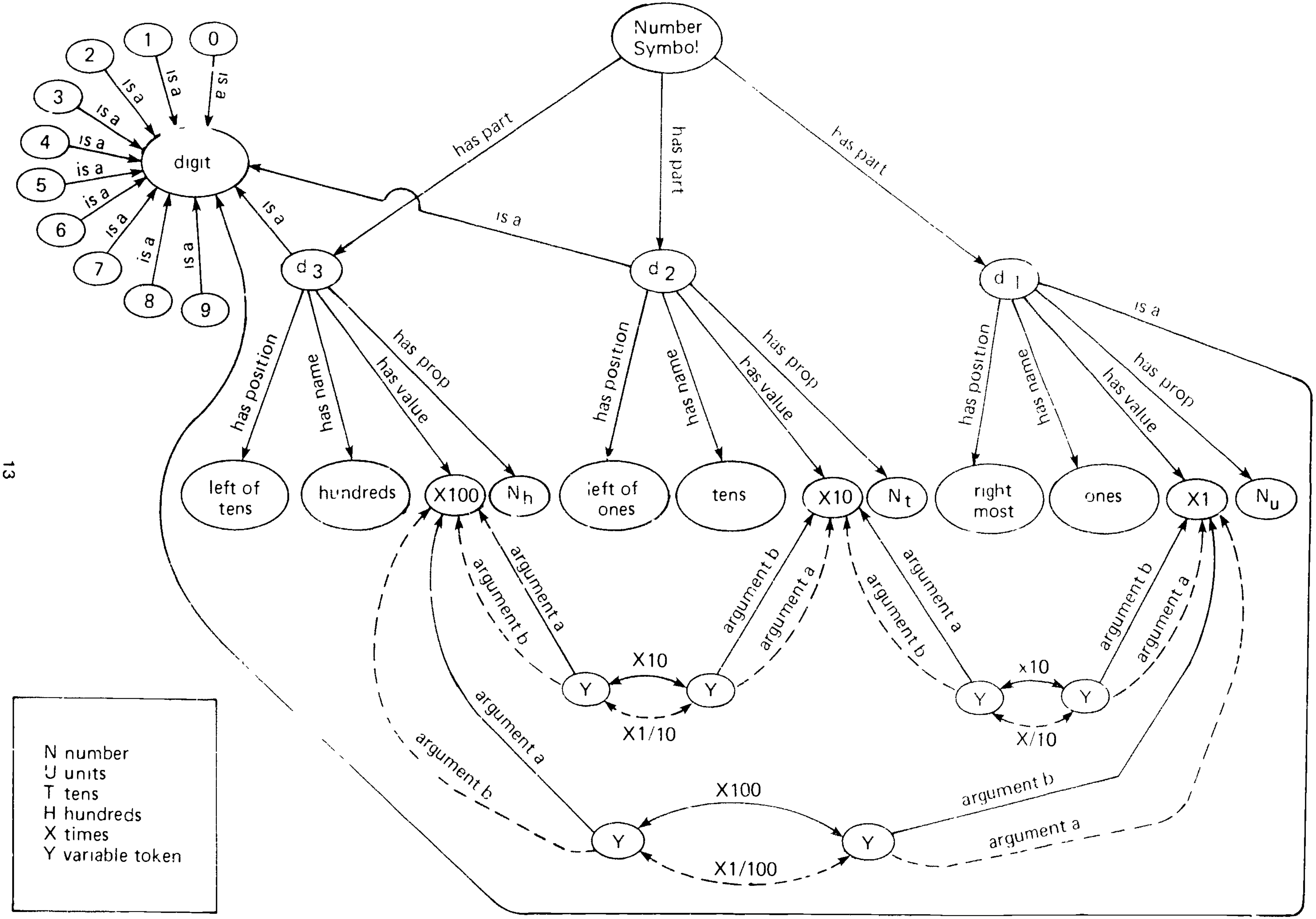

Figure 3. Semantic net information contained in a number symbol

The examples, subtraction with regrouping and numeration, used to illustrate how thinking skills can be taught, are topics from the standard mathematics There are, however, examples that could be developed using the content of the vocational curriculum For example, consider the reasoning skills embodied in clothing construction laying a pattern on a piece of material Without explicit direction, it requires considerable mental ability to place the pattern pieces so that sleeves are mirror images In the same context, consider the thinking skill required to make a pattern one size larger or smaller. There is no reason that concepts like symmetry and scale must necessarily be learned in mathematics or science Vocational courses are rich with contexts in which such concepts and their associated reasoning processes can be learned This important learning can be accomplished if the teacher makes the students aware of the generic procedures and concepts embodied in the physical systems the students are using. The teacher must also make explicit to the students how the procedures and concepts learned in one context are applicable in other situations. As the abstraction becomes a part of students' mental apparatus, the students will begin to recognize other systems and situations in which the concepts and procedures can be applied

Instruction that produces understanding is detailed, explicitly links physical operations to mental ones, and makes students aware of how procedures learned in one context can be applied to other contexts Procedures and concepts are the foundation for problem-solving and reasoning skills These are embedded in practical, everyday situations and operations such as measuring, cutting, and mixing materials—contexts and operations that are integral to the curriculum of vocational education For many students who have experienced failure in traditional science and math courses, the vocational education context might well be the context in which thinking skills can best be learned

1

IF the goal is to do a subtraction problem

AND all the columns have been processed

THEN STOP

2

IF the goal is to do a subtraction problem

AND the no columns have been processed

THEN set a subgoal to process the columns of the problem in sequence

3

IF the goal is to process the columns of the problem in sequence

AND no columns have been processed

THEN set a subgoal to subtract the bottom number of the current column from the top number of the current column

AND mark the right most column as the current column

4

IF the goal is to process the columns of the problem in sequence

AND a column has just been processed

AND another column is to the left of that column

THEN mark the column to the left of the just processed column as the current column

5

IF the goal is to process the columns of the problem in sequence

AND all columns have been processed

THEN Pop the Goal

6

IF the goal is to subtract the bottom number of the current column from the top number of the current column

AND there is no bottom number

THEN
- (a) set the bottom number to zero
- (b) subtract the bottom number from the top number to obtain the answer number
- (c) write the answer number below the line in the current column
- (d) Pop the Goal

7

IF the goal is to subtract the bottom number of the current column from the top number of the current column

AND the bottom number is less than or equal to the top number

THEN
- (a) subtract the bottom number from the top number to obtain the answer number
- (b) write the answer number below the line in the current column
- (c) Pop the Goal

8

IF the goal is to subtract the bottom number of the current column from the top number of the right most column

AND the bottom number is greater than the top number

THEN set a subgoal to borrow

9

IF the goal is to borrow

THEN
- (a) mark the column to the left of the current column as the borrow column
- (b) mark the top number in the borrow column as the borrow number

Figure 4. Production system—SUBTRACT SYNTACTIC

10

IF the goal is to borrow

AND the borrow number equals zero

THEN
- (a) mark the column to the left of the borrow column as the borrow column
- (b) mark the number in the borrow column at the borrow number

11

IF the goal is to borrow

AND the borrow number is equal to or greater than one

AND the column to the immediate right of the borrow column is not the current column

THEN
- (a) subtract one from the borrow number to find the difference
- (b) write a slash on top of the borrow number
- (c) write the difference in the column above the crossed out borrow number
- (d) write a small one above and to the left of the number in the column to the right, placing it within the column bounds
- (e) rename the borrow column as the column one column to the right of the present borrow column
- (f) the top number in the borrow column is marked as the borrow number

12

IF the goal is to borrow

AND the borrow number is greater than or equal to one

AND the current column is to the immediate right of the borrow column

THEN
- (a) subtract one from the borrow number to find the difference
- (b) write a slash on top of the borrow number
- (c) write the difference in the column above the crossed out borrow column
- (d) write a small one above and to the left of the current column number, placing it within the column bounds
- (e) Pop the Goal

Figure 4. Production system—SUBTRACT SYNTACTIC (continued)

QUESTIONS AND ANSWERS

Audrey Champagne

Question: What effect will increased graduation requirements have on basic skills attainment? Also, what new methods are being used in teaching math?

In response to the first question, at best, my guess is that we will not see improvement in the attainment of basic skills We'll see more dropouts as a result of the increased requirements if they are enforced If we cannot get a decent level of understanding of the basic skills, arithmetic computation, and reading by the end of six or eight grades, trying to go over the same old ground with the same old teaching methods in the high school is not going to result in significant achievement This philosophy of toughening up without improving the opportunity to learn will just cause many kids to drop out of school earlier There are few new methods for teaching mathematics being developed and the good ideas that are available are not getting into the schools Students are spending much time doing mimeographed sheets of drill If you take a close look at those sheets, you will often find that kids are drilling themselves in their errors, that a kid may not know what 6 x 8 is and will do 25 sheets and get 6 x 8 wrong on every one of them I don't see that there are any real changes taking place in instruction In fact, I would argue that in elementary math there is very little instruction at all Mostly, it is a matter of "turn to page 14 and do 25 examples," and this is the procedure that you follow. Very little explanation is given of why or how it works

Question: What changes should be made in teacher education? In the structure of schools themselves?

My comments about elementary teachers teaching math were not meant to be a uniform condemnation of what is happening in the schools, but I think on the whole what I said is true for over 50 percent of the teachers. What is going to happen to teacher education? I see a couple of things happening there One has to do with the kind of people schools of education are trying to attract into the teaching profession I hear a great deal of talk about "getting better people to go into teaching " So one part of the formula in teacher education is attracting better people into teaching Now this is an interesting question at this point in time, because people with backgrounds in, for example, math, science, or some vocational areas can make a more substantial salary in industry or business than they can in teaching The other side of the coin is that once you get these "better" people into schools of education, what is it you're going to do with them? Frankly, I haven't heard anything yet that sounds revolutionary in terms of helping teachers do a better job of teaching math and science One effort I am watching with great interest, however, is at the University of California at Berkeley Jim Greeno, who used to be at the University of Pittsburgh, is setting up a teacher education program at Berkeley where they are trying quite deliberately to apply some of the new cognitive psychology to the teaching of mathematics and science It will be very interesting to see the results

Question: Should vocational teachers try to teach and reinforce the basics, or should their attitudes be, "If students haven't learned them yet, they won't"?

First of all, I said that given the amount of time spent in teaching arithmetic in grades K-6, if the kids have not learned in that amount of time using our current instructional methodology, putting them through 6 more years of the same kind of instruction is not going to help That is part one Part two is *if* we can find the right kind of instruction for *that* person, the individual can learn I happen to think that vocational education has some positive things to offer in terms of helping students who traditionally have not done well in the basic skills given the current kind of instruction I think that many girls, and some boys, are turned off to learning mathematics or science, however, if you are talking about learning something about an automobile in auto mechanics, if you are talking about carpentry or dressmaking, I think you can, perhaps, encourage people to learn that skill or that particular trade Then the trick is to teach some of the mathematical and scientific concepts that are embodied in those particular skills or trades. However, the person teaching has to know what these concepts are and has to be able to help the student see that these concepts, these principles, these ideas, are embodied in the vocational situation

Question: Our discussion has been a blend of pedagogy and discussion of what we would like to do about learning and trying to get to a higher order of skills However, we are also dealing with public policy as it relates to graduation requirements and federal law in terms of vocational education Then we are saying that we are not getting the three R's taught and we're talking about imposing more rigorous math and communication requirements in the six grades If you think, then, of vocational education's options and concerns, we could set up admission requirements. Also I think that in many of the vocational classes, the appeal to redefine the basics in terms of higher order thinking skills would be very acceptable

You and I have a different reading on what the public expectations are It seems to me that 5 years ago, the notion reading, writing, arithmetic, computation, decoding, and spelling were the things that the public wanted and was really arguing for. So much that I read now references problem-solving, higher order cognitive skills. Look, for example, at the National Institute of Education's request for proposal. But the most important point is that from a learning perspective, you cannot separate basic performance skills (reading and arithmetic) from basic thinking skills.

The fact is, typical vocational students are a standard deviation below the mean in traditional basic skills achievement If you get them in vocational classes, however, and you do a good job of teaching what you know best, then you will probably bring up their scores

This actually happens, but the data say they graduate as far behind the college preparatory students as when we got them So that is the data, no matter what the experience is

I hear exactly the same kind of question from people in the universities who ask, what we do about the students who come to us who don't have the skills that they need to be successful in college courses. Do we say we are going to remediate them or do we teach them what they need to know as we teach the new material. It seems to me it is a do-it-yourself operation. The kindergarten teacher complains that the parents have not done a good job of preparing the students, the third-grade teacher blames it on the second-grade teacher I think you have to take the kids where they are and try to figure out the best possible way of integrating both the problem-solving skills and the basic skills

Question: How do you react to the notion that science is a basic skill?

Is science learning a basic skill? The answer depends upon who you ask A researcher from the Johns Hopkins Center did a study where he went around and asked employers what specific information, knowledge, and processes from science the employers wanted their potential employees to know or to have. None of the employers came up with one, so certainly employers do not see that specific scientific knowledge is useful in the workplace Why then have states mandated more science predicated on the notion that the American economy is going downhill fast?

I think that the thinking of the legislators goes something like this People who have majored in mathematics and science in college seem like bright people They have good problem solving skills It must be that studying science and mathematics somehow makes smarter people, better thinkers, better problem solvers, better learners In point of fact, I think, the more correct interpretation is probably that given the generally poor instruction in American schools in those subject areas, it is only people who are extremely smart and very highly motivated who get out So instead of science and mathematics learning somehow producing smarter people it is only the smarter ones that can possibly get out with a degree in those areas

What I hear you saying is that if you were to predict the future you would say that five years from now we cannot expect that the traditional basic skill attainment of people coming into vocational education would be significantly better than it is now

My reading on statistics is that if you start looking at kids in the third or fourth grade where there has been a big push in the basic skills, they are doing better in computation, for example Whether that will continue to hold or not I do not know, but in those areas where we have been doing some serious work, you should be seeing some improvement in the kids as you get them into vocational education programs

Question: Can you comment on some of the "misconception research?"

I alluded to it initially I am really trying to make a point that all in all we are not doing a very good job of teaching any of the kids much of anything There is a large body of research in science education that says that after having studied science, the kids still have the same ideas about the physical world that they had when they started the science courses They may have learned a lot of factual information, but in terms of developing any basic understanding of science, they haven't done it

Question: What are American schools doing well?

The National Institute of Education is doing a huge study to see how the Japanese are teaching because the Japanese are obviously doing a much better job of teaching mathematics than we are Japanese girls are doing better than American boys in mathematics At the same time the Japanese are coming over to the United States to study what we are doing because we seem to be a lot better at figuring out really good new designs of computers The whole question of creativity comes into this debate on the basics It is a very interesting question of balance in teaching If you have rigid procedural teaching it is not likely that you are going to get the kind of flexibility in thought, the kind of background that is necessary for creative kinds of thinking But your tests on standardized achievement tests may be great Whatever is wrong with the American school system we still seem to have fairly creative people out there in terms of coming up with new ideas

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