Some Thoughts on Reasoning Capacities
Implicitly Expected of College Students

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INTRODUCTION

In most text materials, homework problems, and lecture presentations encountered in college-level study of natural sciences, social sciences, and humanities, it is tacitly assumed that the students are already in command of a variety of thinking, reasoning, and linguistic processes. An attempt is made in this paper to identify and make explicit some of the more important tacit assumptions. Among the assumed capacities are reasoning patterns characterizing Piaget's category of formal operations, but there are also expected patterns of still higher complexity and sophistication.

In recent years the administration of Piagetian tasks in logical reasoning has revealed that a very large proportion of college students tend to use predominantly concrete as opposed to formal patterns of reasoning. This observation points to a profound discrepancy between most secondary-school- and college-level course content on the one hand, and the actual student reasoning patterns on the other: most course presentations assume that students are generally prepared to utilize formal reasoning processes.

Efforts are currently being made to devise ways of enhancing formal reasoning skills and to reduce this discrepancy. This suggests that one should examine in greater detail the common assumptions about modes and processes of student reasoning—beyond the Piagetian examples—which are implicit in college-level course materials. Bloom (1956) defined a taxonomy of educational objectives which encompasses some general skills and defines a very broad framework for curriculum design. My objective is different; it is to help isolate those reasoning abilities which are commonly and often inappropriately assumed to exist in all college students. What varieties of thinking, reasoning, and linguistic skills are tacitly assumed to be already available to the students? What further skills can be identified as implied objectives in undergraduate instruction?

Putting aside questions concerning the extent to which such reasoning capacities may or may not be developed in the student population, and also deferring questions about possible methods of instruction that might foster the development of such skills, this paper concerns itself only with identifying what

1. Some of the content of this paper was originally developed in a discussion group which was part of the Symposium on Learning in Adolescence, held in connection with the bicentennial celebration of Phillips Academy, Andover, Massachusetts in February 1978.

appear to be some of the most important assumptions about student reasoning processes and levels of preparedness. No pretense is made that the listing is complete or exhaustive; no hierarchical ordering is intended. The goal, rather, is to examine our tacit assumptions and develop a higher degree of awareness of them. It should be clear from what follows that the reasoning processes identified are not confined to physics or the natural sciences exclusively, but arise in every area of study requiring logical thought.

RATIONAL AND LINGUISTIC PROCESSES
IMPLICITLY EXPECTED OF COLLEGE STUDENTS

Recognition, Identification, and Control of Variables

It is generally expected that students can recognize and control, or weigh variables in setting up experiments or in solving verbal problems in the natural and social sciences. For example, they should be able to account for the possible influence of length, diameter, and composition in the well-known Piagetian task of the bending of rods; then control two of these variables in establishing the effect of the third. Similarly, the interpretation of historical phenomena requires recognition and sorting of political and social factors within the information available, following which the student must decide whether cause-and-effect relationships are discernable or whether the variables are so confounded as to preclude a reliable inference. Economics, political science, and experimental psychology all depend upon student facility in dealing with similar considerations of variables and their relations.

Arithmetical Reasoning

Ratio reasoning is required for predicting the alteration of gravitational or electric forces between point objects with changes of mass, charge, or spacing. Similarly, the use of scale ratios is necessary for interpreting maps, determining sizes of objects viewed under a microscope, or for comparing relative changes in volumes and surface (or cross-sectional) areas with changes of scale. Further, it is useful to relate such arithmetical changes to, say, the disproportionately large cross-sections of bones in larger animals, or to the rapidity of the dissolving of a material under finer subdivision. The use of similar kinds of ratio reasoning in connection with demographic data may be required in political science or sociology, and in connection with scaling of factors or rates in economic problems.

Interpretation of division is needed in dealing with concepts of density, velocity, or acceleration in physics; moles, gas behavior in chemistry; and in the study of population and other growth rates in biology. Combinatorial problems arise in elementary genetics, in probability considerations, in control of variables, and in design of experiments.

Forming and Comprehending Propositional Statements

Formation of intelligible propositional statements requires an intuitive grasp of the rules of logic, and of the grammar in which such statements are to be made. For example, forming or understanding verbal statements involves inclusion, exclusion, and serial ordering. In addition, one must grasp syntactical constructions such as double negatives, subjunctive mood, and the capacity to deal with elementary one- or two-step syllogistic reasoning. This is not meant to
include involved propositional logic in which one is forced towards symbols or Boolean algebra for elucidation. The basic skill indicated, however, applies to all areas of study which require the use of language.

**Ability to Paraphrase Paragraph of Text in One's Own Words**

This expectation is applicable to all areas of study. A word of warning is needed here; students may be able to rephrase a paragraph using language similar to that in the text without understanding its content. Thus the insistence that they put it in their own words is of critical importance.

**Awareness of Gaps in Knowledge or Information**

This problem has two dimensions—gaps in the student’s own knowledge, or incompleteness of known information in a given area of study. In the former case, it is expected that when a student fails to recognize the meaning of a word or symbol used in an oral presentation or a passage of a text, he or she will sense the need for establishing its meaning, and have the motivation to do whatever is necessary to establish it.

When the problem is incompleteness of information in a particular context, the student should realize that a definite conclusion cannot be reached; or should note that conclusions or decisions are being reached in the face of incomplete data and hence that such conclusions must be qualified accordingly. This overlaps with problems of psychological maturity, upon which depends the capacity to recognize and tolerate ambiguity in the material under study.

In a sequence of development of a given subject matter, the student is expected to gradually distinguish what has become known or clearly established at any particular point from what has not been so established. This implies learning to anticipate some of the questions still to be asked.

**Understanding the Need for Operational Definitions**

In general, students are expected to learn the criteria by which it is possible to determine whether or not a definition is operational. These criteria include: realizing when a concept in a passage of text has not been clearly defined; recognizing the necessity of using only words of prior definition in forming a new definition; becoming aware of the appeal to shared experience in forming operational definitions.

**Translating Words into Written Symbols and Written Symbols into Words**

The skills necessary for such operations are more rigorous than those needed for paraphrasing textual passages. Examples include: transforming a verbal statement into its equivalent arithmetical, algebraic, or graphical form in any of the natural or social sciences; interpreting a graphical presentation or the results of a symbolic problem solution in words, extracting its content while expressing the relevant qualifications and restrictions.

**Discriminating between Observation and Inference**

Students in all academic disciplines must learn to recognize the observational, empirical, or experimental facts that are available in a text presentation or in laboratory work. The next step is to separate these clearly from the con-
cepts that may be formed or the inferences that may be drawn from them. An example of this would be identifying observed facts concerning the extent of illumination of the moon relative to its position with respect to the sun and then separating these from the inference that moonlight is reflected sunlight. Another example would be distinguishing the observed behavior of electrical circuits (that bulbs get dimmer as more are put in series at the same source) from the concept of “resistance” which is induced from the observed behavior. In this particular case, further distinctions would then need to be made between inferences concerning the nature of electrical resistance, and the predictions that can be made concerning phenomena in more complicated circuits.

Other examples from quite different areas of inquiry include: separating Mendel’s observations of nearly integral ratios of population members having different color or size characteristics from the inference of discrete elements controlling inheritance; the distinction—common in the study of literature—between analysis of the structure of a novel, or poem and an interpretation of the work; and the historian’s task of recognizing the distinction between primary historical data and his own interpretation of such data.

**Analyzing a Line of Reasoning in Terms of Underlying Assumptions**

Every line of reasoning has an underlying set of assumptions separate from the factual data it may utilize. Students need to develop the capacity first to discover and second to distinguish among assumptions, assertions, and reasoned conclusions.

**Drawing Inferences from Data and Evidence, Including Correlational Reasoning**

Separate from the analysis of another’s line of reasoning comes the formulation of one’s own. For example, given the observation that the spot formed on the screen by the cathode beam (Thompson’s experiment) remains coherent (i.e. does not smear out) under both electric and magnetic deflection, what inferences can be drawn concerning the origin and character of the beam? Or: given the code of laws of Hammurabi, what—if anything—can be inferred about how the people subject to it lived, and what they held to be of value? Yet another example is the problem of recognizing possible functional or cause-and-effect relationships in either positive or negative correlations in the face of statistical scatter or uncertainty; for example, discerning relative or competing effects of light, heat, or moisture on a biological population (with a simultaneous awareness of whether or not the variables have been adequately controlled).

**Ability to Discriminate Between Inductive and Deductive Reasoning**

Students should be able to follow inductive reasoning used in generating a concept, model, or theory, and use deductive reasoning in testing the validity of a construct. They should perceive the analogous patterns of scientific thought arising in such broadly diverse areas as the Newtonian Synthesis, wave versus particle models of light, atomic-molecular theory, gene theory, theory of evolution, economic or sociological models of society or its parts, and so on.

**Performing Hypothetico-deductive Reasoning**

Students should be able to visualize, in the abstract, outcomes that might
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stem from changes imposed on a given system or situation, whether it be in scientific, literary, historical, economic, or political contexts, and effect such visualizations through reasoning within the basic principles or other rational constraints applicable to the system.

Performing Qualitative, Phenomenological Reasoning or Thinking

In science and mathematics, the ability to recall formulas and manipulate them algebraically does not by itself indicate complete understanding of a subject area. Students should also be able to give qualitative explanations of principles and make direct inferences from them without referring to the results of numerical calculations. They should be able to apply phenomenological reasoning without relying on mathematical formalism.

Checking Inferences, Conclusions, or Results

Skills in this category include: testing for internal consistency; using alternative paths of reasoning; examining extreme, limiting or special cases.

In some instances, only initial or preliminary levels of the skills listed in the preceding section are actually presupposed in college work at introductory levels, while enhancement and further development of such skills are often implicit objectives of the courses of instruction. In addition to these objectives, others are at least implied, when not explicitly articulated, in most statements of the cognitive goals of higher education. Two of these more general goals which subsume many of the preceding objectives can be articulated as follows.

Developing Self-consciousness Concerning One's Own Thinking and Reasoning Processes

It is generally desired that students learn to become explicitly aware of the mode of reasoning being used in particular situations. This provides the basis for consciously seeking to transfer familiar modes of reasoning to new and unfamiliar situations. In general, students should learn to attack a new problem or unfamiliar situation by first forming very simple related problems, by asking themselves questions derived from the simplest and most concrete aspects that seem to underlie the given situation.

Developing the Skills of One's Discipline

Finally, students are expected to combine the preceding modes and processes into the general skills of problem solving as practiced by the discipline(s) of choice.

COMMENTS AND CONCLUSION

In forming the preceding list, an effort has been made to isolate and describe reasoning modes and processes—together with levels of awareness that appear to be bound up with clear thinking and genuine understanding in various disciplines; and to indicate that such processes are common to very different subject-matter areas. However, this description of assumed student capacities (or course objectives) does not constitute a prescription for how such capacities are to be attained.

In designing procedures for assisting student development, we need to be
sensitive to styles of learning; balance of verbal, visual, and auditory presentation; the question of which subject-matter areas may be the most suitable starting points for different individuals; and in general, the volume, pace and level of materials presented. It must not be forgotten, however, that the reasoning modes and processes proper to academic inquiry are skills that must be mastered—they are not a matter of style or preference. I have recently attempted to design a course in physical science which encourages student growth along many of these lines (Arons, 1977); readers interested in instructional techniques are referred to this work as one example of a curriculum oriented toward some of the preceding goals.

In recent years, the administration to college students of typical Piagetian tasks characterizing formal patterns of reasoning has revealed that at least 50 percent in the broad cross section completely fail to perform the tasks or perform them with only partial success. In general, these tasks probe only a few items among the capacities listed in this paper and do not probe the more sophisticated capacities or those involving verbal-linguistic aspects. Inquiry among secondary school and college teachers usually yields quick, subjective denial that an appreciable fraction of the students exhibit these capacities. Yet much of the material and instruction with which students are confronted implicitly assume that the reasoning capacities are either already developed, or that they will automatically evolve with maturation and the study of the subject matter.

It is becoming embarrassingly clear that such automatic development actually occurs in only a relatively small proportion of our students—perhaps the upper 25 percent, those whom we characterize as among the "brightest." The remainder, who might well develop such intellectual capacities at a slower pace, are not afforded the opportunity to do so. They need the time to reason slowly, to make mistakes and retrace their steps without being crushed or punished; to revise their thinking and test it themselves for internal consistency. Under pressure of the volume and pace of material with which they are deluged, many students seek refuge in blind memorization and completely lose sight of the intellectual processes through which they could bring order into the chaos that seems to surround them. As a matter of fact they never develop any sense of their own intellect or of the deeply satisfying feeling that emerges when one recognizes that he understands something.

In order to cultivate the development of the reasoning capacities listed above, it is necessary to give students time, explicit help and encouragement, and repeated practice in all subject-matter areas. It is also necessary to enhance their consciousness of thought processes by urging them to stand back and examine the reasoning processes in which they have engaged, and to express them in their own words. When this is conscientiously done, even if it be at the expense of "coverage" of subject matter, students develop an entirely new intellectual stance, characterized by heightened respect for their own intellect and by pride of achievement. In consequence they begin to be conscious of the speciousness of the rewards they received in circumstances in which they were driven to memorize without understanding, and they are motivated to attack still more demanding inquiry without giving up readily on encountering difficulty or temporary frustration. In other words, to quote Justice Learned Hand's ironic phrases, they become more "willing to engage in the intolerable labor of thought—that most distasteful of all our activities."
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Justice Hand used this line in a discussion of the circumstances under which liberties might be preserved in a democratic society. His basic thesis was the absolute necessity of a thinking, reasoning citizenry. What capacities characterize such a citizenry? The sophisticated distinction between enlightened self-interest as opposed to short-range self-interest must be based on hypothetico-deductive reasoning. Such reasoning is also inevitably involved in visualizing possible outcomes of different policies and decisions in economic and political contexts concerning which one must exercise a vote. There is a repeated need to discriminate between facts and inferences in the contentions with which one is surrounded. There is the necessity for making tentative judgments or decisions, and it is better that this be done in full awareness of gaps in existing available data, knowledge, or information. There is the highly desirable capacity to ask critical, probing, fruitful questions concerning situations in which one has no initial expertise. There is the need of being explicitly conscious of the momentary boundaries of one's own knowledge and understanding of a particular problem. Every one of these capacities appears in our list and can be cultivated and enhanced, at least to some degree, in the great majority of college students through properly designed programs embracing a wide variety of subject matter. Thus there is reason to hope that an educational framework, consciously designed to develop the reasoning capacities of college students, can enhance their professional careers and make them more responsible citizens of a democratic society.

REFERENCES
